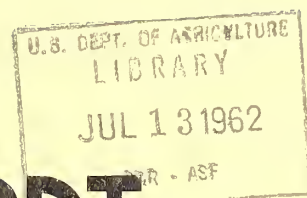


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ANNUAL REPORT

1961



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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Fort Collins, Colorado

Raymond Price, Director

✓
FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

PROJECT LOCATIONS

Albuquerque, New Mexico
Marron Hall
University of New Mexico

Flagstaff, Arizona
Arizona State College

Fort Collins, Colorado
Forestry Building
Colorado State University

Laramie, Wyoming
Agriculture Building
University of Wyoming

Lincoln, Nebraska
Plant Industry Building
University of Nebraska

Rapid City, South Dakota
South Dakota School of Mines
and Technology

Tempe, Arizona
Agriculture Building
Arizona State College

Tucson, Arizona
University of Arizona

Station headquarters is at Fort Collins, Colorado,
in cooperation with Colorado State University

ANNUAL REPORT

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CALENDAR YEAR 1961

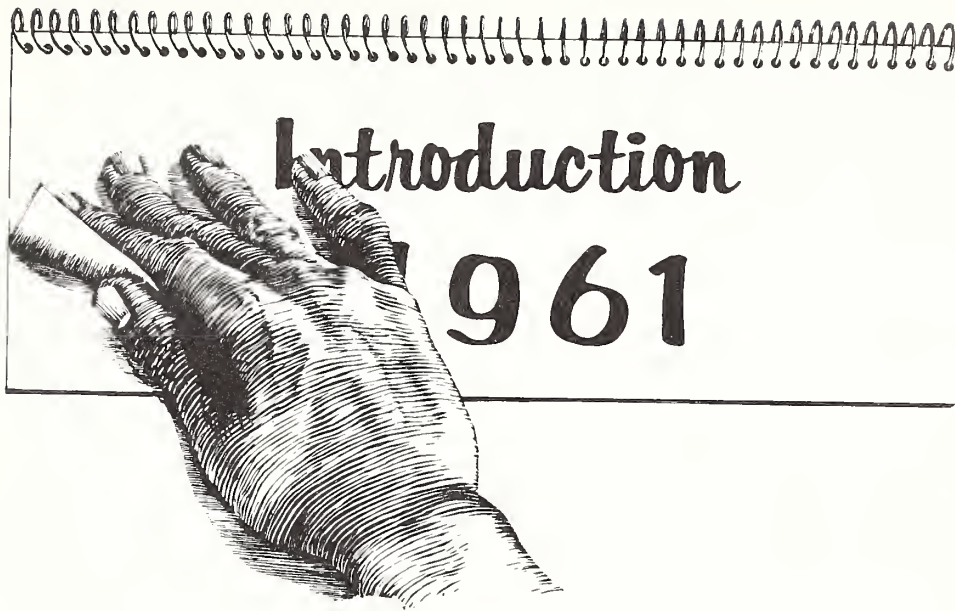
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Location of the Forest and Range Experiment Stations and the Forest Products Laboratory



Timber management research in ponderosa pine in the Southwest is becoming increasingly occupied with shaping young growth into productive forests of the future. Past harvest cuttings have removed the high-risk trees from the stands. Most of the timber losses through the death of overmature and mature trees, a continuing process in unmanaged forests, has been halted. Future treatments, therefore, can now be directed toward converting existing stands into vigorous, productive forests and to reforestation of understocked lands.

Research is being started to determine the kind of stand structure that will produce the best yields and quality, and to learn the best ways of converting existing stands to the desired structure. The best levels of growing stock for different sizes and structures of stands that have been indicated by older studies are being refined. Quality of yields can be improved by pruning, and up to 70 percent of the total height of stems can be pruned with little influence in growth.

Planting of southwestern ponderosa pine can be successful. Plantings made by four different methods have survived well when good quality stock was used on well-prepared sites.

Seed was found to be viable after 35 years of storage.

Forest fire control was advanced by two publications that explain the basis and use of the 2-index system of rating fire danger, and by learning that the drought index can be used to estimate soil moisture under chaparral. Some guides to aid intentional burning of chaparral were developed. These depend upon moisture variations in shrub live oaks and upon mechanical and chemical treatments prior to burning.

Forest insect research is being focused on the biological factors that help control forest insect pests. When these natural enemies are inadequate, outbreaks often become serious. A thorough understanding of the biological factors involved aids in finding ways to detect, predict, and prevent these lapses in nature. When lapses or severe outbreaks do occur and chemical control becomes necessary, we need information about the biological factors to know when to apply the insecticides. Our research is presently concentrated on the nematode parasites of the more important bark beetles, woodpeckers that feed on bark beetles, microbial diseases of the Great Basin tent caterpillar, and the insect parasites and predators of the spruce budworm.

Forest disease research reports that greenhouse inoculations and field observations not only confirmed preliminary evidence that bearberry serves as alternate host for the spruce broom rust fungus; it also revealed that the fungus alternates to greenleaf manzanita in northern Arizona. Research in the aspen type indicated that a number of different cankers are widely distributed but not abundant throughout the central Rocky Mountains, and that the presence of *Fomes ignarius* fruiting bodies does not justify culling entire trees. In a continuation of dwarfmistletoe studies, it was found that these parasites must produce bumper crops of seeds to cause heavy infection, because only a small proportion of the seeds are intercepted by trees. High-speed photography was used in studies of the ballistics of seed flight. Research in the central Great Plains revealed that dothistroma needle cast is abundant but not damaging in ponderosa and Austrian pines in Nebraska windbreaks, but phytophthora canker is both abundant and damaging in Russian-olive. Western-X virus of chokecherry was transmitted by budding, and tests are underway to determine whether it can also be carried in chokecherry seeds.

Forest utilization research reveals that the generally soft lumber market that has prevailed during the past year has emphasized the need for development of improved guidelines for evaluating timber and for planning its utilization. Results of studies in timber quality and related utilization fields offer promising leads for segregating logs by quality classes, along with possible outlets for problem lumber grades.

Continued research in watershed management shows that the possibility of increasing streamflow by changing plant cover on headwater watersheds is intriguing. Results from some pilot tests are promising. Strip cutting in sub-alpine forests is already a standard practice for many National Forest areas and is favoring water yield. In some areas, management for maximum water yield may be more difficult to combine with timber management, but measures for bettering quality and quantity of timber production in ponderosa pine are not reducing flow from a test watershed in Arizona. Chaparral watersheds challenge research because of the apparent potential for increased waterflow, but this is accompanied by high erosion and sediment.

More effective and efficient methods for repairing damaged watershed areas are being sought. High labor cost and new machines have outdated formerly accepted techniques. Working closely with going action programs, researchers are obtaining an understanding of field problems. Measurements to determine the best kind of plants for stabilizing fire-swept slopes are being made in both Arizona and South Dakota.

Instruments and techniques have been developed to speed up progress and make possible measurements once only a dream. Future reports will show what can be done with these tools.

Range management and wildlife habitat research was highlighted by new and expanding studies. In the central Rocky Mountains the effects of herbicides used to improve livestock ranges on wildlife habitat values and the application of herbicides and other brush and weed control methods as a tool in habitat improvement are being studied. In the Southwest, research will determine the effect of converting chaparral, pinyon-juniper, and other vegetation types on wildlife habitat. This includes control by chemical, fire, and mechanical methods.

Research on the management of alpine-subalpine sheep ranges was expanded in Wyoming. Likewise, research in Arizona on the use and management of chaparral ranges for the production of cattle was expanded. A study of relative productivity of grasses and shrubs as cattle forage was started on the Prescott National Forest in Arizona.

The time the range is grazed determines grass production following mesquite control on semidesert grass-shrub ranges in southern Arizona. On ranges grazed in the late fall-winter-early spring season, when the grasses are dormant, production increased 70 percent in 3 years. Areas grazed yearlong produced only 35 percent more grass, and areas grazed in the late spring-summer-early fall period, when the grasses are growing, showed no improvement.

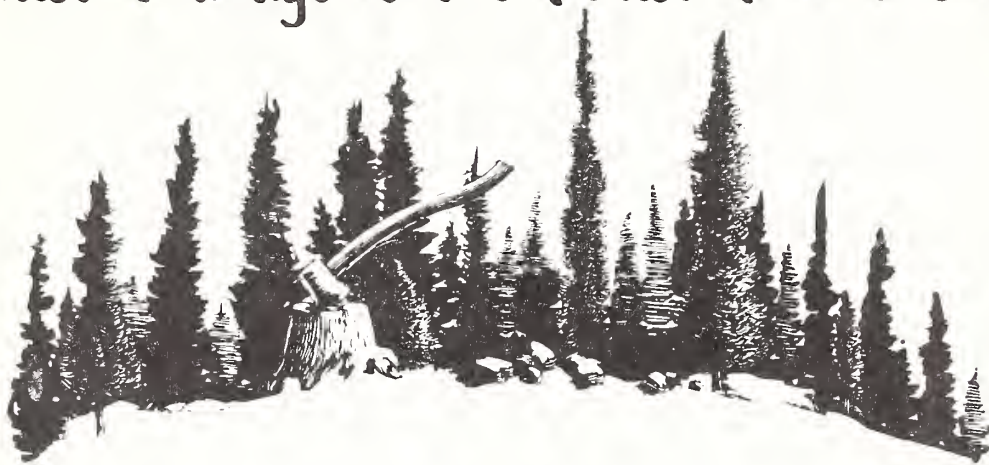
In northern New Mexico it was found that crested wheatgrass is good lambing range. The optimum level of stocking with ewes was about 65 percent use of the crested wheatgrass produced by the end of the spring lambing period. At the end of the 3-year period of grazing at the different rates, no differences in production of crested wheatgrass were found where utilization averaged 39 to 84 percent. However, indications are that grazing in the higher intensities might have detrimental effects if continued for a longer period.

In Wyoming research shows that when Idaho fescue ranges are grazed continuously throughout the summer season, utilization should be approximately 40 to 45 percent of the Idaho fescue by weight. At this rate of utilization, animal gains are near optimum and the range is maintained or improved. Lighter rates of grazing result in higher gains per head per day but lower per-acre gains. Heavier rates produce more gain per acre but less per day; also the range is damaged.

Forest economics research shows substantial opportunities for expanding timber uses of the Rocky Mountain region, particularly the fiber industries. At present more than four-fifths of the timber harvest is for lumber. The concentration of cut on the larger, higher quality trees leaves an overwhelming residue of smaller, lower quality trees. Fortunately, these lesser trees are suitable for fiber use such as pulp. We are now completing a study of resource factors relating to pulpmill development in the headwaters of the Colorado River in Colorado. This report brings together timber-supply, water-supply, and wood-procurement cost data required by companies considering establishing pulpmills here.

Details of these and other findings are presented in the following pages. Complete accounts of our research are released through various publications. An annotated list of publications issued in 1961 is included in the bibliography at the end of this report.

Forest Management & Forest Fire Research



Repeated harvest cuttings reduced mortality in south- western ponderosa pine

Reduction of mortality, a major objective of harvest cutting in virgin stands, has been attained on the Fort Valley Experimental Forest, Arizona. Losses were far less during 20 years following each of two cuttings than for the corresponding periods in a virgin stand (table F-1). Losses were less after the second cut than after the first. All methods of cutting tried (favoring dominants, favoring subordinates, and 35-percent salvage) gave similar results.

Table F-1. --Average numbers of trees and board-foot volumes lost per acre in 20 years¹

Study period	Cut twice		No cutting	
	Trees	Volume	Trees	Volume
	Number	Board feet	Number	Board feet
20 years after first harvest cut	1.49	406	1.21	1,110
20 years after second harvest cut	.52	178	1.43	1,506

¹ Minimum d. b. h. : 7.6 inches for numbers of trees, 11.6 inches for volume.

The reduced mortality reflects the reduction in numbers of large, old, high-risk trees. On the twice-cut areas only 21 percent of the trees that died were larger than 24 inches d.b.h. They represented 64 percent of the volume that was lost, however.

The most important causes of mortality after the first cut were also most important after the second cut. Of the total volume in dead trees after the second cut, 41 percent was due to lightning, 20 percent to dwarfmistletoe, and 10 percent to wind.

Time for decision in ponderosa pine silviculture in the Southwest

Two harvest cuttings in ponderosa pine on the Fort Valley Experimental Forest have accomplished worthwhile goals: mortality of old growth has been reduced to a low level as shown by the preceding article, quality of stands has been improved, and a supply of old growth is still available to support future sawtimber harvests.

All methods of cutting that have been tested have given satisfactory and similar results. They have permitted an orderly removal of the old growth and reproduction has been good.

Now, as the time for a third harvest cutting approaches, two main classes of trees are left: the scattered remainder of old growth and young trees, mostly below sawlog size. Intermediate-size classes are uncommon in many places. An increasingly larger part of the growth capacity of the land is going into young trees. The prescriptions for the third cutting must, therefore, place more emphasis on management of the young growth and less emphasis on improving and "stretching" the old growth. As we get into young-growth management, we will be shaping the structure of the forest of the future.

It is therefore necessary to decide the ultimate structure toward which the stands should be shaped. The most promising are group selection or even-aged structure. Both will be tested and both will embody release and thinning of young stands for rapid development.

Heavy pruning reduces dia- meter growth of southwestern ponderosa pine

Forty percent of the live crown of Arizona ponderosa pines can be removed without significantly affecting diameter growth if at least 30 percent of total tree height is left in live crown. Removing up to 60 percent of the live crown will not materially affect height growth (table F-2).

Four plots in a 20-year-old stand were thinned in 1934 as follows: control, light release of crop trees, moderate release of crop trees, and thinning to a uniform spacing of 8 x 8 feet. In 1948, 16 crop trees per plot were assigned to each of four pruning treatments; control, 20 percent of live crown removed, 40 percent of live crown removed, and 60 percent of live crown removed.

Table F-2. --Average periodic increase in diameter and height by thinning treatment and pruning intensity, 1948-52 and 1953-57

Thinning intensity	Trees per acre	Pruning--proportion of live crown removed							
		1948-52				1953-57			
		None	20	40	60	None	20	40	60
		: percent	: percent	: percent	: percent	: percent	: percent	: percent	: percent
<u>Periodic increase in diameter at breast height (inches)</u>									
Control	5,576	0.33	0.40	0.26	0.16	0.26	0.34	0.24	0.21
Light release	3,729	.50	.43	.38	.23	.36	.32	.34	.26
Moderate release	3,851	.45	.40	.46	.20	.35	.30	.37	.27
8 x 8 ft. spacing	1,612	.60	.48	.45	.28	.41	.34	.38	.31
<u>Periodic increase in diameter at 9 feet (inches)</u>									
Control	5,576	.54	.70	.54	.40	.32	.29	.26	.22
Light release	3,729	.62	.53	.48	.38	.42	.39	.34	.25
Moderate release	3,851	.72	.67	.63	.42	.41	.38	.43	.33
8 x 8 ft. spacing	1,612	.84	.69	.68	.42	.43	.34	.36	.31
<u>Periodic increase in height (feet)</u>									
Control	5,576	3.07	3.11	2.91	3.11	2.65	2.86	2.81	2.34
Light release	3,729	4.46	3.51	4.02	4.36	3.31	3.55	3.57	3.34
Moderate release	3,851	3.62	3.72	3.83	3.35	3.51	2.90	3.01	2.81
8 x 8 ft. spacing	1,612	4.51	4.68	4.56	4.47	3.71	3.26	2.91	3.07

First-year survival of
ponderosa pine plantations
in Arizona is encouraging

Two ponderosa pine plantations near Flagstaff, Arizona, survived well through the 1960 growing season.

The Coconino National Forest used four methods to plant 9,600 2-1 transplants on an area burned in 1959. The plantation was fenced to exclude cattle. Transplants were sprayed with TMTD (tetramethylthiuramdisulfide) to prevent browsing by mule deer. Survival to September 1, 1960, was fairly uniform for all methods, averaging 76 percent, as shown below:

<u>Method of planting</u>	<u>Survival (Percent)</u>
Standard planting, to depth of root collar	78
Standard planting, with three-rock mulch (fig. F-1)	76
Deep planting (to terminal bud), no mulch	79
Deep planting, with three-rock mulch	<u>73</u>
Average survival	76

An experimental planting of 1,280 seedlings by the same four methods was made on a 10-year-old burn inside a deer-proof fence on plots scalped as shown in table F-3. Overall survival in October 1960 was 92 percent.

Table F-3. --First-year survival of 2-1 ponderosa pine by planting method and scalping treatment

Treatment	Standard planting		Deep planting		Average
	No	Three-rock	No	Three-rock	
	mulch	mulch	mulch	mulch	
- - - - - <u>Survival percent</u> - - - - -					
No scalping (control)	76	92	80	78	82
Spots scalped 16 inches in diameter	91	99	90	90	92
Spots scalped 26 inches in diameter	96	95	95	95	95
Spots completely scalped	98	98	95	96	97
Average	90	96	90	90	92

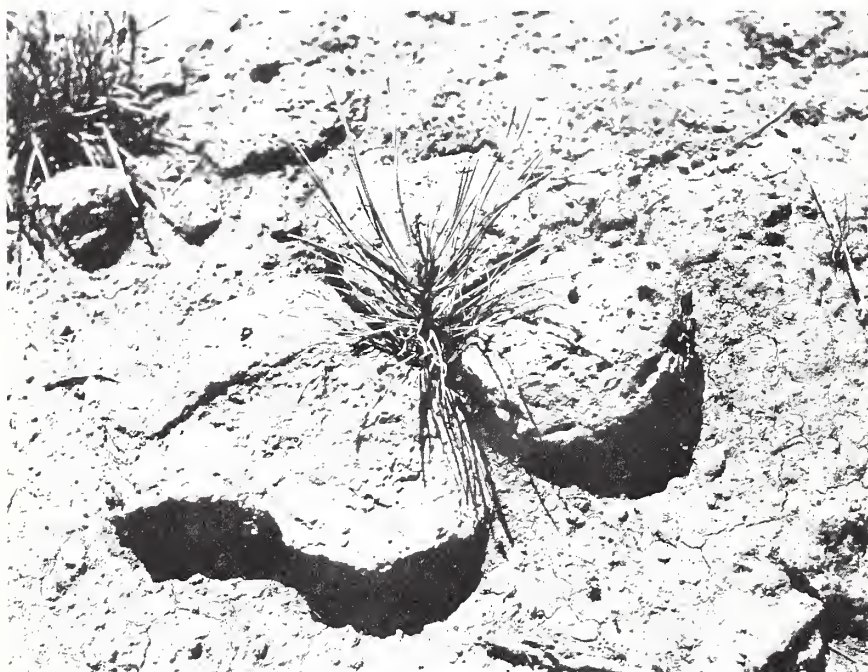


Figure F-1. --Ponderosa pine transplant (2-1) planted to standard depth with three-rock mulch.

Thirty-five-year-old
ponderosa pine seeds
still viable

Ponderosa pine seeds germinated after 35 years of storage (Table F-4).

Table F-4. --Percent of filled seed, germination percentages, and moisture contents of various age ponderosa pine seeds planted in moist sand on November 15, 1960

Year collected	Filled seed ¹	Total ger- mination	Filled seeds ger- minating	Days to reach 50 pct. ger- mination	Moisture content (ovendry weight)
	Percent	Percent	Percent	Number	Percent
1909	78.0	0	0	--	8.7
1921	84.0	0	0	--	7.5
1925	92.0	16.0	17.0	--	8.7
1933	79.0	36.0	46.0	--	6.2
1948	--	46.0	--	--	8.6
1950	98.0	70.0	71.0	12.0	7.9
1956	90.0	74.0	82.0	14.0	8.1
1958	71.0	72.0	100.0	12.0	9.3
1959	72.0	65.0	90.0	15.0	13.1
1960	99.0	97.0	98.0	13.0	9.4

¹ 1960 seeds were soaked in water to separate sound from unsound seeds.
Seed treatment for other years is not known.

Seeds collected in northern Arizona from 1909 to 1960 were stored until November 1960, then germinated. Storage was in glass jars in a cool root cellar until 1958 and in a house thereafter. Maximum air temperature in the house probably reached 80° F. during the summer. Moisture content of the seeds collected in all years except 1959 was under 10 percent when removed from storage.

Porcupines damage Black
Hills ponderosa pine

Nearly 10 percent of 7,364 trees examined in a 1958-59 survey had been injured by porcupines (fig. F-2). Three-fourths of the trees attacked will have permanently deformed stems.

Classes of trees attacked most frequently included thrifty dominants and codominants and trees 6 to 8 inches in diameter at breast height. Preferred stands included those on lower slopes, those close to openings of an acre or more, and those of 200 to 700 trees per acre.



A, Complete girdling of the stem.

B, Death of the tree top.



Figure F-2. --Stages in deformation of a tree following attack by porcupines.



C, Crooked multiple stems formed by side branches that turned into leaders.

As thinning increases in the Black Hills, more stands will be shaped to contain trees and stands in the preferred categories. Since thinning is aimed at reducing stands to desired densities of the best trees available, continued porcupine damage in thinned stands could cause serious management problems.

Moisture remains high in
leaves of shrub live oak dur
ing years of normal rainfall

The moisture in leaves of shrub live oak has remained between 80 and 90 percent of oven-dry weight for 3 years of near-normal rainfall, except in the spring when new leaves appear. New leaves contain approximately 180 percent moisture, but after 6 to 8 weeks drops to the 80 to 100 percent range.

Bad wildfires occur in Arizona chaparral only during drought years. None were recorded in the years in which leaf moisture was measured. Apparently shrub live oak is not very flammable when the leaves remain so moist.

Mechanical and chemical treatment
aids burning of shrub live oak brush
in Arizona

Chemical treatment of shrub live oak kills and dries the leaves but has little influence on branchwood. Mechanical treatment that severs branches provides fewer dead and dry leaves, but more dry wood.

Treatments to aid burning of shrub live oak bushes were applied in the spring of 1960 as follows:

1. Cutting one or more stems of a bush and placing it at the base of the bush or leaving it stand.
2. Crushing bushes with a tractor.
3. Crushing bushes with a disk.
4. Treating with fenuron.
5. Treating with 2, 4, 5-T.

Chemically treated oaks should be burned after the leaves die and dry, but before they fall. Individual bushes were burned in October 1960 and April 1961. By October, the 2, 4, 5-T treatment had killed the leaves but the leaves were still on the bushes. Fenuron-treated bushes were still green. The 2, 4, 5-T-treated bushes burned well; the fenuron-treated bushes did not. By April, the leaves had fallen from the 2, 4, 5-T-treated bushes and they burned poorly. The fenuron-treated bushes were then dead but the leaves were still intact. They burned well.

Mechanical treatments that increased the amount of dead branchwood at the base of shrubs substantially aided burning. Treatments that left similar volumes of dead branchwood standing were not as effective.

Basis and use of 2-index fire
danger rating system explained

A fire danger rating system is more than a method of rating fire danger. Used properly, it is an integral part of systematic fire control from fire prevention to suppression. The basis for the 2-index system was detailed in the July 1961 issue of the Journal of Forestry under the title, "Development of the 2-index system of rating forest fire danger." Instructions for operation and many suggestions for application of the system to different aspects of fire control were released in Station Paper No. 63.

Drought index holds promise
in chaparral type

Drought index, as the name implies, indicates the influence of cumulative precipitation deficiency on the moisture in forest fuels and related materials, including soils. Moisture in soils is significant in fire danger rating, as it is the source of moisture for living fuels. When soils dry, green fire-retarding vegetation also tends to become dry, fire-carrying fuel.

Although designed to rate drought effects in the ponderosa pine type, drought index may apply to Arizona chaparral also. The moisture in a soil occupied by chaparral correlated well with drought index (fig. F-3). Whether it is typical for all chaparral-occupied soils to be drier than soils in the pine type for the same levels of drought index, or whether the differences in figure F-3 are due to soil texture, will require further testing.

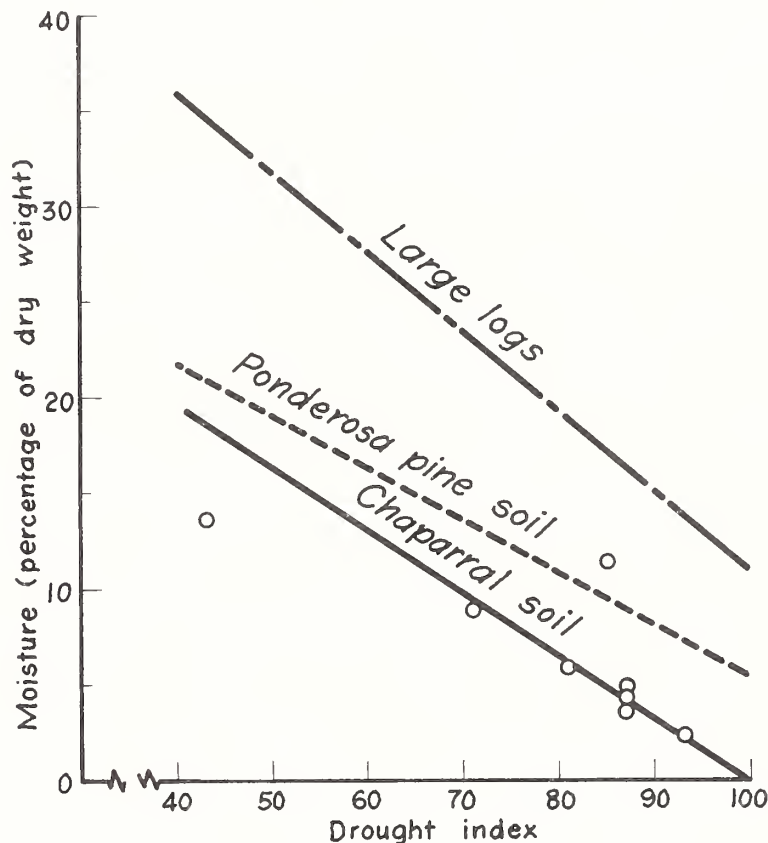
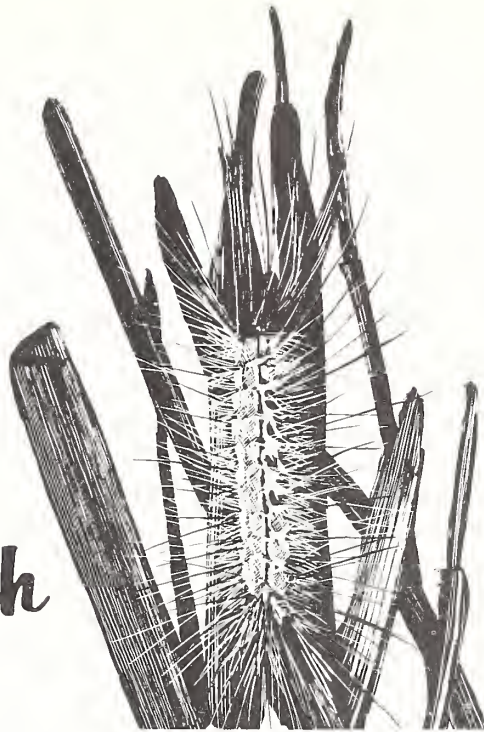


Figure F-3. --The relationship of the moisture content of two soils and large logs to drought index. Points are for a "chaparral soil." As the line for ponderosa pine soil was converted from inches of water in soil to percent soil moisture, its position is approximate.

Forest Insect Research



Nematode parasites of bark
beetles are numerous

Little was known about the nematodes parasitic on bark beetles and their value as biological control factors until the recent and current work of the Rocky Mountain Forest and Range Experiment Station. Many of the species were new. These had to be classified and described before the biological studies could proceed. Fourteen new parasitic species were taken from bark beetles. Ten of them have since been described. Nine new species, which are predaceous in habit, also were discovered and described. The Station collection of nematodes taken from or associated with bark beetles now contains 30 genera, each of which is represented by 1 to 10 species.

One of the species, Aphelenchulus elongatus, was selected for life history studies because of the ease of rearing its bark beetle host, Ips confusus. A brief summary of its life cycle, starting with adult female nematode in the body cavity of the adult bark beetle, was found to be as follows: Eggs are deposited in the abdominal cavity of the beetle; the larvae from these eggs penetrate the gut and pass with the fecal matter into the egg gallery constructed by the beetle; the nemas live within the insect galleries until they mate and infect the new beetle larvae through the body walls; only the female nemas enter the beetle larvae; the females continue to grow, becoming mature only after the insect pupae transform to beetles. The mature female nemas are about one-sixth of an inch long. One to seven nemas may develop in each insect, each laying about 1,400 eggs. The maximum number of nema eggs and larvae found in one beetle was 5,775.

The nemas do not kill the beetles but do curtail the number of eggs that are produced. In the tests to determine these biological control effects, the infested females produced only 30 percent as much brood as the noninfested females. Also, the infested beetles are less vigorous and construct significantly shorter egg galleries.

Beetle progeny were more likely to be infested with the parasites when the parent female beetles were infested; 47 percent of the progeny was infested when the female parent alone contained egg-laying nemas, 53 percent when both parents were infested, and 6.2 percent when only the male parent was infested.

It is too early in our studies to know the total effects of nematodes on bark beetle populations and whether they can be manipulated for more effective biological control.

Biological factors controlling local Engelmann spruce beetle outbreak

Studies and observations of many Engelmann spruce beetle outbreaks in Colorado since 1944 show that (1) all originated from blowdown or cull logs; (2) the smaller outbreaks were biologically controlled within 2 or 3 years after going into standing trees; and (3) the larger outbreaks required chemicals or trap trees to augment the work by the woodpeckers and other natural-control factors to effect adequate control. Biological control agents in addition to woodpeckers include nematodes, mites, insect parasites and predators, and micro-organisms. In order to learn more about the mode of action and combined effect of these biological control agents, an outbreak in northern Colorado was followed from its beginning to end.

Large beetle populations bred in cull logs that accumulated from the harvest of 11 million board feet of lumber cut in 1953 and 1954. This cull due to rot amounted to 15 percent of the timber harvested (fig. 1-1). The beetles that emerged from the cull in 1957 infested 1,150 trees. In 1958, 460 trees were infested; in 1959 only a few trees were infested; and in 1960 no trees were infested.

Brood survival of each of the three generations was measured at approximately weekly intervals through the summer, fall, and spring. The findings, based on bark samples 1-foot square, were as follows:

	Generation beginning in July		
	1957	1958	1959
	- - - - (Number) - - - -		
Pairs of parent beetles	10	12	16
Progeny survival:			
July - - Eggs and first-stage larvae	--	248	185
Sept. - - Partial to full-grown larvae	277	125	75
June - - Partial to full-grown larvae	38	8	28
Sept. - - New adults	18	6	2
	- - - - (Percent) - - - -		
Progeny mortality	94	98	99

The number of attacks (pairs of parent beetles) per square foot of bark increased each year with each generation, yet the density of eggs and small larvae decreased. This could have been caused by increased parasitism by nematodes and a decrease in vigor of the beetles. Other causes of mortality during the egg and small larval stages were from encasement in resin and predation by mites. Competition for food between spruce beetle larvae and other bark beetle larvae also was a factor but could not be measured. The mortality between July (egg and early larval stages) and September (the partially to fully grown stages) amounted to approximately 50 percent. The mortality from woodpecker feeding from September to the following June probably contributed most to the outbreak decline. Many larvae that escaped the woodpeckers later died from desiccation that resulted from the removal of bark. From June to September of the second year, two species of insect parasites killed 18 percent of the surviving larvae. By September when the Engelmann spruce beetle normally reaches the adult stage and enters winter hibernation, only 6 percent of the progeny of the 1957 generation had survived, or 18 progeny from 20 parents; only 2 percent of the 1958 generation, or 6 progeny from 24 parents; and only 1 percent of the 1959 generation, or 2 progeny from 32 parents. Obviously, the surviving population was not sufficient to continue the outbreak. The potency of the biological control agents was clearly demonstrated.



Figure I-1. --Unmerchantable cull logs were the breeding sites for the Engelmann spruce beetle outbreak.

Woodpeckers aggregate in
Engelmann spruce beetle
outbreaks

Woodpeckers are the most important natural enemy of the Engelmann spruce beetle, often consuming up to 98 percent of the overwintering population of larvae (fig. I-2). They have stopped many beetle infestations in the incipient outbreak stage.



Figure I-2. --Woodpeckers remove much of the bark to feed on Engelmann spruce beetle larvae.

A field study of woodpeckers overwintering at a local epidemic of the beetle in a high-altitude spruce-fir forest of southern Colorado revealed valuable information about their habits and how they aggregate in an infestation. Through the winter, three species of woodpeckers, northern three-toed, the hairy, and the downy, were concentrated in the infestations in about equal numbers. In one afternoon in March, 60 to 90 woodpeckers were found on a 2-acre tract. The downy and hairy woodpeckers left the areas for lower elevations in the spring, the former starting in March, the latter in May. The three-toed woodpeckers were permanent residents of the spruce forests. During the daylight hours of the winter, the birds aggregated at the infested trees. At the end of the day they dispersed to the peripheral areas, many birds going more than one-half mile away. The woodpeckers suffered from considerable predation through the winter while concentrated in the beetle-infested areas. At the onset of the breeding season, the three-toed woodpeckers redistributed themselves at a density of about 6 pairs per square mile. No large aggregations of woodpeckers were seen in the beetle infestation during the breeding season. This may have been due in part to the depletion of the supply of Engelmann spruce beetle. After this depletion, the woodpeckers turned increasingly to secondary bark beetles and other bark and wood-inhabiting insects.

A standard for predicting damage by the spruce budworm

The current spruce budworm epidemic in the spruce-fir stands of northern New Mexico and in Colorado grosses nearly 1,800,000 acres. This is a reflection of the insect's high biotic potential, an abundance of host material, and a low incidence of natural factors of control. The epidemic has grown in severity during the past 10 years, and resultant tree mortality due to defoliation is increasing. Abundant egg production in 1961 and the evident paucity of effective biological control suggests a high budworm survival and a continuance in 1962 of severe damage (fig. I-3).

A standard of measurement based on egg mass density per unit of foliage is used for predicting budworm damage. Such a standard is used in the Pacific Northwest. This standard is developed by relating egg abundance to subsequent defoliation. Masses of budworm eggs are laid by female moths on the underside of host needles (fig. I-4). This is a characteristic of the spruce budworm throughout its range, coast to coast. Observations and measurements of egg masses and defoliation in Colorado since 1959 have permitted an adaptation to the following standard which for New Mexico and Colorado depicts the relationship between egg mass densities in August and defoliation the next year.

<u>Egg masses per thousand</u> <u>square inches of foliage</u>	<u>Defoliation</u> <u>percent</u>
1	5
2	10
3 to 5	25
6 to 10	50
11 to 16	75
17 to 20	90
21 or more	95 to 100



Figure I-3. --

High populations of the spruce budworm cause critical loss of foliage.

Figure I-4. --

Eggs of the spruce budworm are laid on the underside of the needles. The average number of eggs per mass is 23.



Causes of Great Basin
tent caterpillar outbreaks
being studied

Each year the Great Basin tent caterpillar defoliates thousands of acres of aspen in northern New Mexico and southern Colorado (fig. I-5). After a few years of consecutive defoliation, the tops die, and after 5 years many trees may die. This same caterpillar is found in other parts of the central and southern Rocky Mountains but never in outbreak proportions. We are now intensively studying the habits of the pest to learn what in the environment allows it to generate outbreak populations in some areas and not in others. Once these limiting factors are known, they may be used to our advantage in controlling the population in the troublesome areas. The life cycle is as follows: The moths lay their eggs in masses on twigs in July (fig. I-6); in about 3 weeks each egg contains a fully developed first-stage larva ready for overwintering; the eggs hatch the latter part of May; molt five times; reach full growth in late June and pupate; moths emerge in 10 days; mating is immediate; each female lays one egg mass containing about 150 eggs.



Figure I-5. --
Thousands of
acres of aspen
are defoliated
annually by the
Great Basin
tent caterpillar
in northern
New Mexico
and southern
Colorado.

Approximately 25 percent of the pupae were killed by insect parasites (fig. I-7). An insect parasite was also reared from approximately 90 percent of all egg masses tested; however, only 5 percent of the eggs in the masses were destroyed. Caterpillars killed by a naturally occurring polyhidrosis virus disease were common throughout the study areas during 1960 and 1961. More than 90 percent of the colonies contained virus-killed caterpillars. These biological factors, even though present in large numbers, are not effecting economic control of the pest. More than 10 new egg masses were deposited on each tree, which is sufficient to continue the outbreaks in the study areas. We plan to follow several outbreaks annually to learn what factors in the environment eventually effect control.

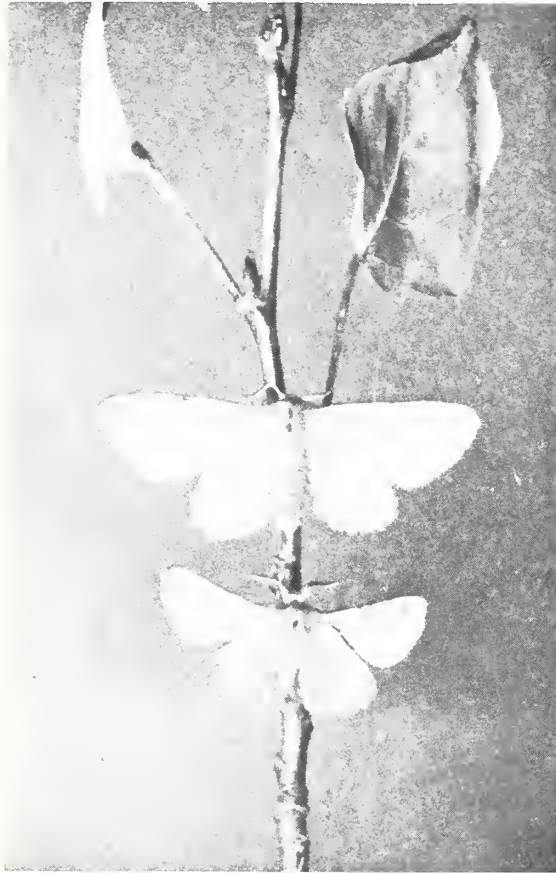


Figure I-6. --Female and male moths of the Great Basin tent caterpillar emerge in July and deposit eggs in masses on the twigs.

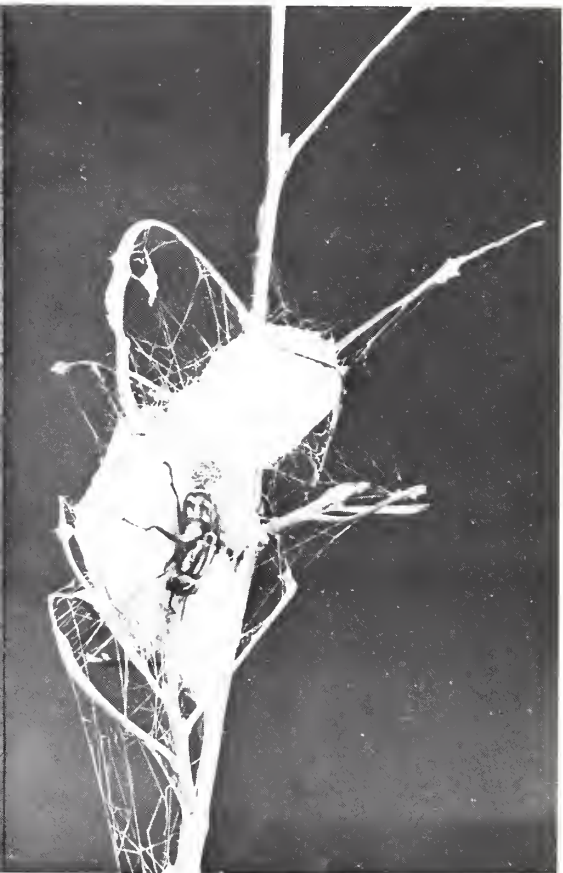


Figure I-7. --An adult of an insect parasite resting on cocoons of the Great Basintent caterpillars. This parasite, along with others and disease-causing organisms, are valuable natural-control agents.



Forest Disease Research

Aspen cankers are wide-spread but not abundant

Aspen is subject to a larger number and a wider variety of stem cankers than any other forest tree in the central Rocky Mountains. Some cankers, such as cytospora canker are caused by weak parasites and may have little or no significance except in trees that are declining from other causes. Other cankers such as hypoxylon canker (fig. D-1) and sooty-bark canker (fig. D-2) are caused by recognized pathogens and can be important factors in the deterioration of otherwise healthy stands. Still others such as black canker (fig. D-3) and nectria-like canker (fig. D-4) are striking in appearance, but little or nothing is known about their cause or importance.

Casual observations can often be misleading in gaging the importance of canker diseases. For this reason information on the distribution of aspen cankers was obtained on 31 clusters (four 1/10-acre plots per cluster) on the Roosevelt, Routt, San Juan, Grand Mesa-Uncompahgre, and White River National Forests of Colorado. In all, 4,075 trees were examined. Nine percent of the trees were dead. The proportions of live and dead trees with cankers were as follows:

<u>Canker</u>	<u>Cause</u>	<u>Live trees</u> (Percent)	<u>Dead trees</u> (Percent)
Cytospora	<u>Cytospora chrysosperma</u>	4	54
Black	Unknown	3	9
Sooty-bark	<u>Cenangium singulare</u>	2	51
Nectria-like	Unknown	1	--
Hypoxylon	<u>Hypoxylon pruinaum</u>	0.2	2

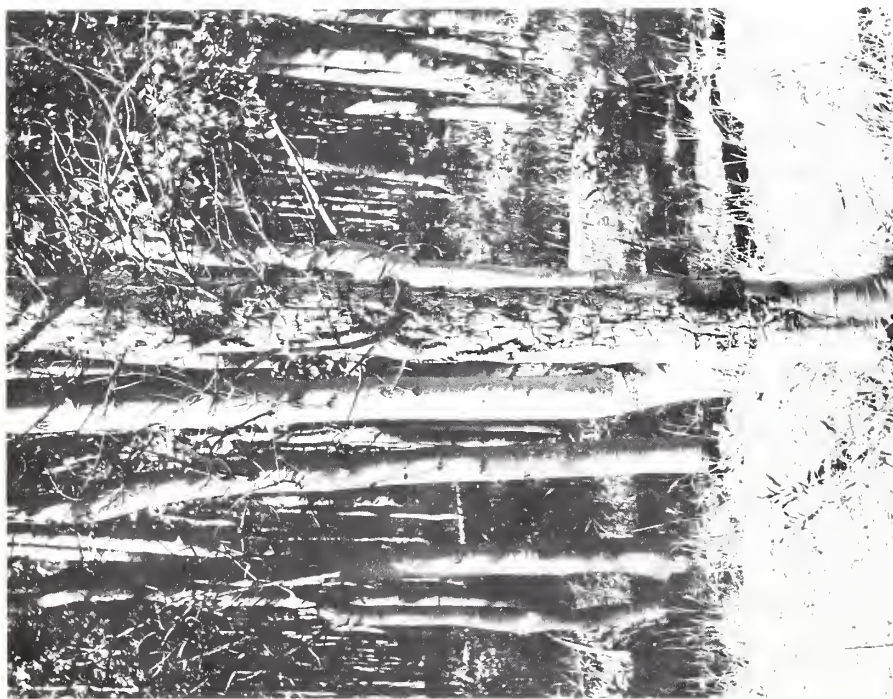


Figure D-1. --Aspen canker: Hypoxylon canker caused by Hypoxylon pruinatum.

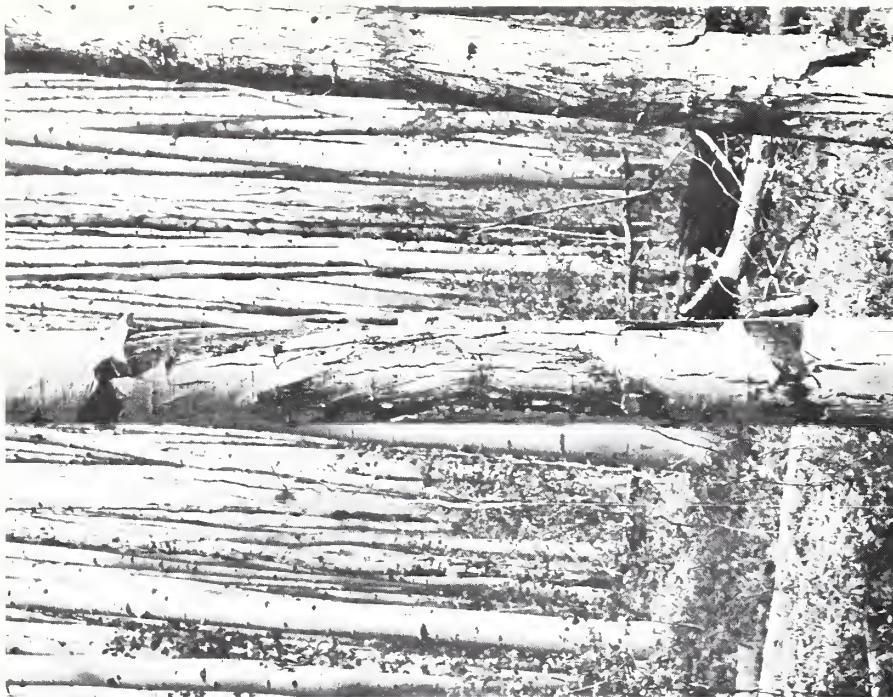


Figure D-2. --Aspen canker: Sooty-bark canker caused by Cenangium singulare.



Figure D-3. --Aspen canker: Black canker of unknown cause.

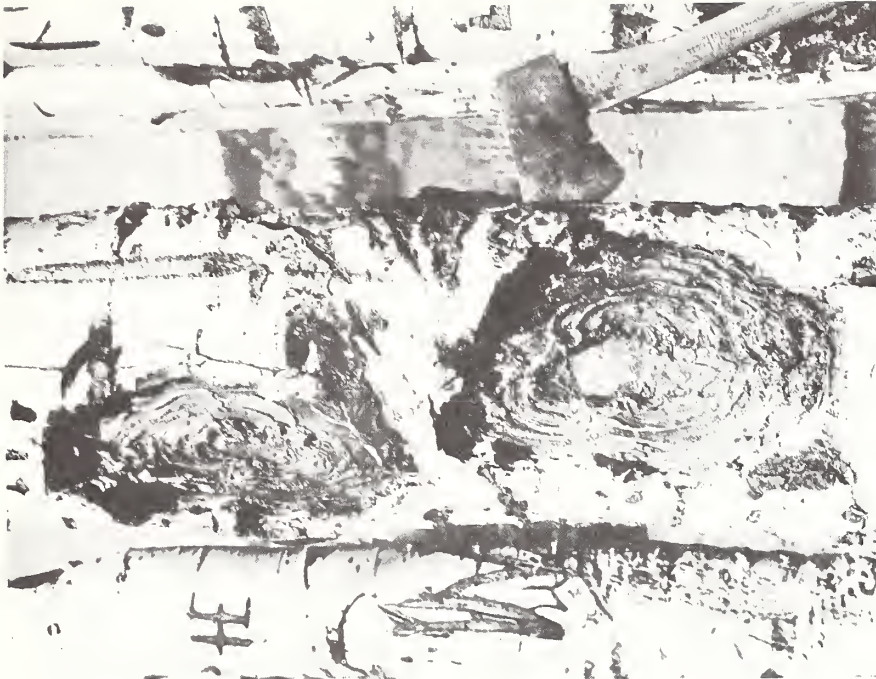


Figure D-4. --Aspen canker: Nectria-like canker of unknown cause.

Sooty-bark canker and cytospora canker both occurred on 81 percent of the clusters. Black canker was present on 65 percent of the clusters, whereas Nectric-like canker and hypoxylon canker were found on only 35 and 16 percent of the clusters, respectively.

Aspens with Fomes igniarius fruiting
bodies are not always culls

The most important wood decaying fungus in aspen is Fomes igniarius var. populinus (New.) Campb. In commercial aspen stands in Colorado, trees bearing fruiting bodies of this fungus (fig. D-5) are usually considered to be culls, but a recent dissection study of 113 trees on 11 areas in 5 National Forests of Colorado suggests that this practice results in considerable waste. The study revealed that height of the highest fruiting body on a tree is a more reliable indicator of cull than the number of fruiting bodies. For example: when the average height of the highest fruiting body was 5 feet, cull averaged 18 percent of the cubic foot volume or 50 percent of the board foot volume; and when the average height was 12 feet, comparable cull percents were 25 and 65. Rejection of all trees with fruiting bodies is clearly unjustified when the unit of measure is cubic feet.

Western-X virus trans-
mitted by budding

The incidence of Western-X virus disease of chokecherry is high in wind-break plantings and native stands in Nebraska. The virus has been successfully transmitted from diseased to healthy trees by budding, thus paving the way for tests to determine whether the virus can be transmitted through chokecherry seeds.

Dothistroma needle cast
found on windbreak pines

Needle cast caused by Dothistroma pini and tip blight caused by Diplodia pinea are present in Nebraska and have caused considerable damage in city plantings, but it is not known whether they are present and causing significant damage in field windbreaks. A recent survey of 20- to 22-year-old windbreaks in 10 Nebraska counties revealed that needle cast was widespread but not damaging in 1960; it was found on 198 of 987 ponderosa pines and on 164 of 400 Austrian pines. Tip blight was not observed in either species in the same 20- to 22-year-old windbreaks and seems to be of no consequence at the present time.

Bearberry and greenleaf
manzanita are alternate
hosts of spruce broom rust

The fungus causing witches'-broom rust of spruce, a widespread and locally abundant disease, was proved by repeated inoculations in the greenhouse to

Figure D-5. --

Fruiting body of
Fomes ignarius
var. populinus
on aspen.



complete its life cycle on bearberry or kinnikinnik (Arctostaphylos uva-ursi). Thus, the name of the bearberry rust fungus, Chrysomyxa arctostaphyli, becomes applicable to the spruce parasite, which has not been classified properly hitherto. Probably host alternation between spruce and Arctostaphylos is obligatory for the fungus. That is, no evidence was found that it can pass directly from spruce to spruce or bearberry to bearberry. Damage to spruce occurs in Arizona south of the range of bearberry, but this is explained by the discovery that greenleaf manzanita (Arctostaphylos patula), abundant in northern Arizona, can also serve as alternate host.

Phytophthora canker is causing
damage to Russian-olive in
Nebraska windbreaks

A canker disease of Russian-olive was found to be widespread and causing considerable damage in 20-year-old windbreaks in Nebraska. Examination of more than 3,000 trees revealed that about one-third of these trees were severely damaged. The causal fungus, presumably a species of Phytophthora, is now being studied in the laboratory and greenhouse.

Bumper crops of dwarfmistletoe
seeds needed to cause serious
infection

In a heavily infected ponderosa pine stand, 20 percent of the dwarfmistletoe (*Arceuthobium vaginatum*) seeds produced were intercepted by trees, and of these seeds 94 percent were intercepted by needles and 6 percent by twigs. The intensity of the first rain following seed discharge appears to be critical in determining the movement of seeds from needles to twigs and increasing the percentage of seeds that are positioned to cause infection. After 1 year, less than 1 percent of the seeds produced on the area were in contact with susceptible host tissues.

High-speed photography used to
study ballistics of dwarfmistletoe
seed flight

An insight into the expulsion mechanism of dwarfmistletoe fruits is being obtained by the use of high-speed photography. At maturity dwarfmistletoe fruit expels the single seed for distances up to 40 feet. Photography using speeds as fast as 1/5000 of a second was not sufficient to obtain a clear image of the seeds in flight. However, such photographs provided the first direct evidence of the expulsion process showing that a large mass of viscous material is violently ejected behind the seed (fig. D-6). Further tests using much faster speeds are planned in hope that more details regarding seed expulsion and flight characteristics may be obtained.



Figure D-6. --Dwarfmistletoe fruit immediately after seed expulsion: A, seed in flight, and B, viscous material forcibly ejected behind the seed.



Forest Utilization Research

Study indicates economic advantages of residue utilization

Pulp chips were produced in Arizona for the first time in 1961. The production of chips creates promising product combination alternatives for sawlogs, historically converted to lumber alone. Potential alternatives are the subject of a current study. The four product combinations considered are:

1. Lumber only,
2. Lumber plus chips from residue,
3. Chips only,
4. Lumber plus chips from lower-grade center cants.

Only logs of grade 3 and poorer were considered in the study.

The study develops a method of appraising and comparing alternatives. It also deals with the effect that these alternatives have upon marginal and break-even log size and grade. Differences between product value and production cost are the basis for comparison between alternatives. As an example, figure U-1 illustrates the surplus of value over total production cost for two alternatives--lumber production, and lumber plus residual chip production. Conversion surplus is, in effect, the amount left to cover stumpage cost and profit. Therefore, for any given stumpage cost and product alternative, break-even log size can be read directly from the horizontal graph axis.

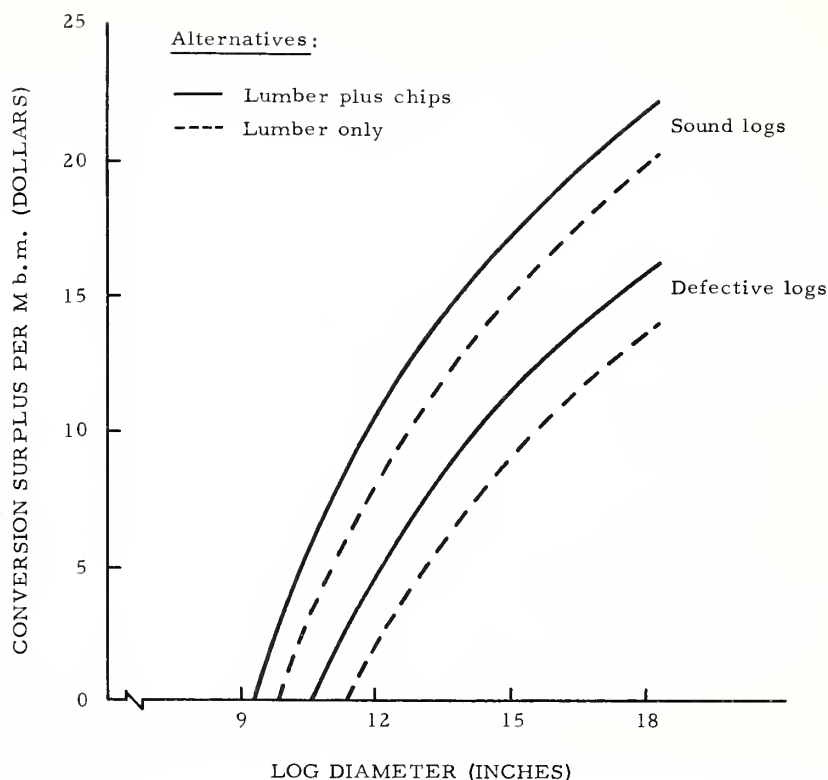


Figure U-1. --Conversion surplus of value over total production costs, combined log grades 3 through 6.

Preliminary results show that the greatest economic benefit is gained from producing lumber plus mill residue chips. The smaller the log, the greater the relative gain realized from chipping residue. Chipping entire logs produces the lowest net return, regardless of log size and grade, and is the least desirable alternative considered.

As part of the study, production costs and product values were determined for each log diameter class and grade. Figure U-2 shows the marked effect of log size upon the profit potential from producing lumber. The effect of the lower size classes emphasizes the need for more efficient and complete utilization of smaller logs.

Service life for commercially treated Black Hills ponderosa pine fenceposts tested

Service life of commercially treated ponderosa pine fenceposts in a market area tributary to Black Hills treating plants will be determined by the use of test plots. Two plots were installed in the semiarid region in western South Dakota on a National Grassland site, and one plot was installed in the more humid region in eastern South Dakota on an experimental tract administered by the South Dakota Agricultural Experiment Station.

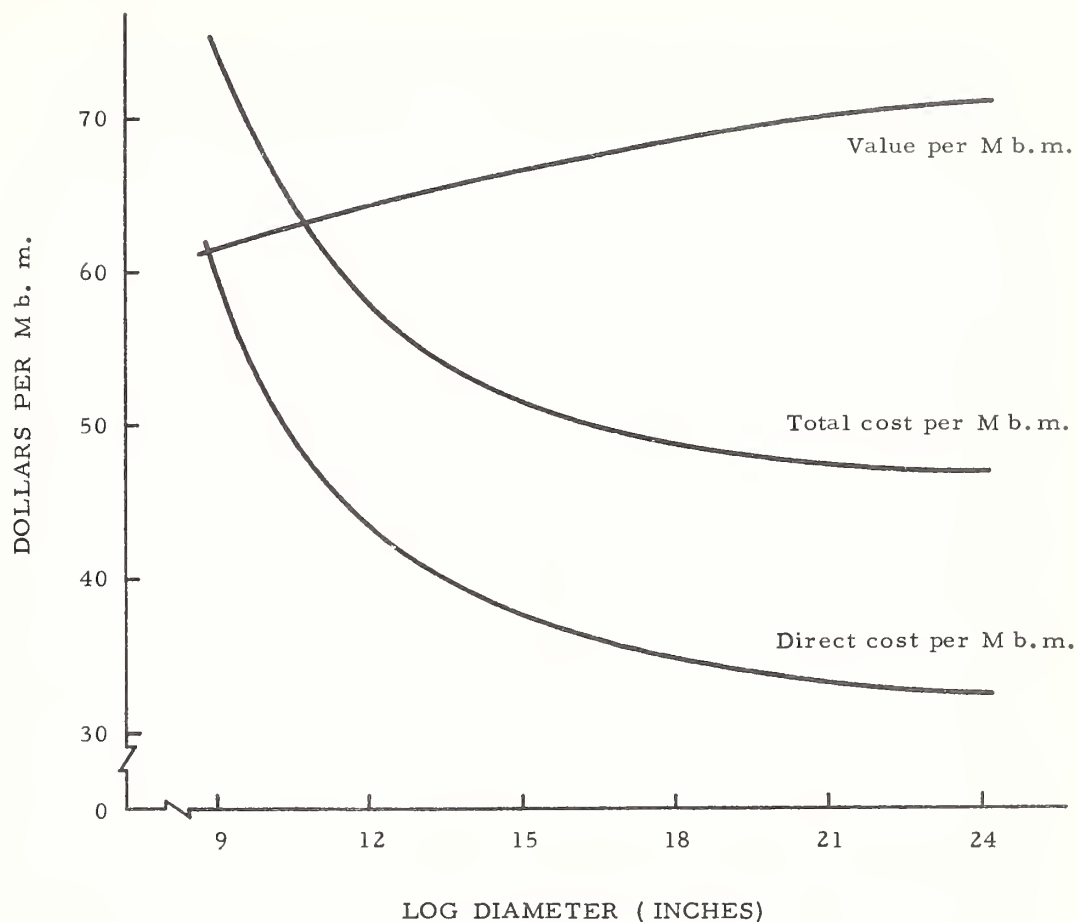


Figure U-2. --Average conversion costs and sales value per M b.m.
dry surfaced lumber, combined log grades 3 through 6.

The posts were measured and then treated at the five treating plants by conventional commercial methods. Each charge was closely followed throughout the treating cycle so that treating procedures could be related to specific groups of posts. Average preservative retention, percent sapwood, preservative penetration, and moisture content were determined.

The posts were treated by pressure creosote, pressure pentachlorophenol, pressure osmosalts, osmoplastic, hot-and-cold bath creosote, and cold-soak pentachlorophenol. One level of preservative retention, 6 pounds per cubic foot, was specified for the pressure creosote and pressure pentachlorophenol methods. Two levels of preservative retention, 3 pounds and 6 pounds per cubic foot, were specified for the cold-soak pentachlorophenol and the hot-and-cold bath creosote methods. Also, two retention levels, 0.35 and 0.55 pound per cubic foot, were specified for the osmosalts pressure method. The retention level was not controlled for the osmoplastic process. In addition to the treated posts, 25 untreated control posts were included in each plot.

The posts will be inspected once a year for 25-30 years and results of the inspections will be made available to the public in periodic progress reports.



Figure U-3. --Service-life test plot located in the more humid region of eastern South Dakota. A similar plot was also established in the semiarid region of western South Dakota. Each plot contains 250 Black Hills ponderosa pine fenceposts treated by nine different methods, including untreated posts. The plots were established in August 1960 and will be inspected each year for the next 25 to 30 years.

Low-grade lumber problem studied in Southwest

A study was conducted throughout the Southwest ponderosa pine belt to determine what might be done to improve the market for the low-common grades of lumber produced in the area. This generally universal problem is more acute in the Southwest region because approximately 40 percent of the lumber produced there is 4 and 5 common. These grades have rarely returned a profit; however under normal markets industry has been able to absorb them.

The study was completed and a final report is being processed. A preliminary draft of the findings and recommendations was reviewed with industry representatives concerned. Highlights showed that the problem is complicated by the fact that it is related to the national trend away from lumber sheathing in building construction, a major market for the lower common grades of lumber. This shift in lumber use has greater impact on the local area than elsewhere because of the higher than average yields in sheathing grades.

Two approaches to the problem were outlined by the study group, a short-range approach and a long-range approach. The short-range approach, which offered most immediate assistance, provided for investigating the production of panel-type products either in form of specialized plywood panels or lumber panels designed to reduce the installed cost of wood. Upgrading the lumber by means of paper overlays or similar masking techniques to make the wood more acceptable and more serviceable was also considered. A number of applications of the overlay principle were outlined in the report which will be available shortly.

The long-range approach involved basic changes in building design to incorporate prefabricated components in which low-grade material could be used effectively and at less cost.

Establishment of a pulpwood market through the completion of present Kraft-groundwood mill presently under construction in Arizona was also considered as a potential outlet for the problem grades. This generally suitable outlet leaves a question as to how much capacity and area it can serve.

Local species included in wood-strength study

Samples of inland Douglas-fir and white fir from the central Rocky Mountains and Southwest regions were included in a comprehensive industry-sponsored wood-strength study. The primary purpose of the study was to provide:

1. More adequate information on the intrinsic strength properties of each major species throughout its range.
2. Better knowledge of the effects of environment and related factors on wood quality.
3. Clues to the occurrence and location of trees that are superior in strength as well as form, growth rate, and other desirable characteristics, to provide breeding stock for future timber stands.

A total of 119 Douglas-fir and 107 white fir trees were sampled in the local study. Sample trees were determined by a presampling technique used to distribute the selected trees over the range of diameters and specific gravities common to the species.

Quality evaluation will be based on wood density, since it is a reliable index of the strength properties of a species. Density determinations were made on increment cores taken at d.b.h. in each tree and on cross-section discs taken at predetermined intervals along the length of the bole. The samples were shipped to the U. S. Forest Products Laboratory for processing and analyses.



Figure U-4. --Increment core taken from sample Douglas-fir tree for wood-density determination. Density is a useful key to many important properties of wood.

Improved log-grade system
developed for ponderosa pine

An improved log-grade system for old-growth ponderosa pine was completed during the year. The new grades culminate several years of compilation and analysis of lumber-grade recovery data collected over the entire commercial range for the species. The development provides an improved basis for evaluating sawtimber and should prove valuable to both the buyer and seller of stumpage as well as to timber managers and manufacturers of forest products.

The improved grades were developed largely from studies of old-growth trees, 150 years and older. It is anticipated that additional specifications may be added for more adequate classification of young-growth logs. A description of the improved grades follows:

Grade 1. --

Primary defects are limited to one, and this one defect may not exceed one-half inch in diameter (a pin knot). It may be located anywhere on the log surface. Primary defects include limbs, limb studs, knots, holes where limbs have broken out, and overgrown knots. Ordinarily no scaling deduction is made for this class of defect, but it is a major indication of lowered lumber grades.

Secondary defects are admitted providing they can be confined within not more than three surface panels of the log. Secondary defects include scars, seams, large burls (one-fourth diameter of log and larger), forks, crooks, and cracks. Scale deductions are often made for secondary defects.

Surface panel is defined as a side or portion of a log covering one-quarter of its circumference and 4 feet long.

Grade 2. --

Primary defects are admitted without limit as to number, provided that they can be confined within four surface panels of the log.

Secondary defects are admitted provided that all grading defects (abnormalities on surface of the log that influence the quality of the lumber than can be sawn from it) can be confined within six surface panels of the log. A log with no primary defects, but with secondary defects affecting up to six surface panels is included in this grade, but a log with primary defects on five surface panels is not admissible, even though it has no secondary defects.

Grade 3. --

Primary and secondary defects are admitted without limit as to number, provided there are at least six surface panels free of all grading defects.

Grade 4. --

Primary defects admitted with following limitations:

1. At least 80 percent must be bark limbs.
2. Size of defect proportioned to log diameter at the point of occurrence:

- a. Bark limb: diameter inside bark at log surface must not exceed one-sixth of log diameter.
 - b. All others: diameter at log surface must not exceed one-twelfth of log diameter.
3. Not more than 24 primary defects at or near maximum size are allowed.

Secondary defects are admitted, provided they can be confined to three surface panels or less.

Grade 5. --

All logs not qualifying for grades 1 through 4 that are otherwise one-third sound by standard U. S. Forest Service scaling procedure.

Trial log grades effective in grading
larger Engelmann spruce logs

Application of the trial log grades developed for associated species in the Pacific Northwest Region to a 672-log sample of Rocky Mountain Engelmann spruce showed that the grading system effectively separated logs in diameters 14 inches and larger. The system did not appear to offer any significant advantage over straight-diameter segregation in diameters under 14 inches. Lumber values for each log-grade diameter class were computed from regression estimates of lumber recovery and log values. Lumber values thus computed, being the product of two regressions, form a smooth curve of value over diameter. Figure U-5 illustrates the resulting lumber value curve for each log grade.

For comparative purposes, figure U-6 is included to show raw-data lumber value for each log diameter class, all log grades combined. The illustrative curve is a balanced freehand curve.

Engelmann spruce yields high proportion
of lumber in better common grades

The low yield of clear or select grades common to Engelmann spruce is generally compensated by the high proportion of lumber recovery in the better common grades, 1c, 2c, and 3c. The situation is further compensated by the small volumes that are generally found in the low common grades, 4c and 5c. Knots are the major degrading defect, and although numerous, they are generally small and sound. The small volume of 5 common present is due largely to presence of rot.

Figure U-7 illustrates the distribution of lumber volumes by lumber grades as segregated by the trial log grades for full-scale and partial-scale logs. The difference in yields of 5 common in the two soundness classes accounts in part for the generally higher overrun from partial-scale logs, as it illustrates that some of the volumes deducted in scaling are recovered in the sawing operation.

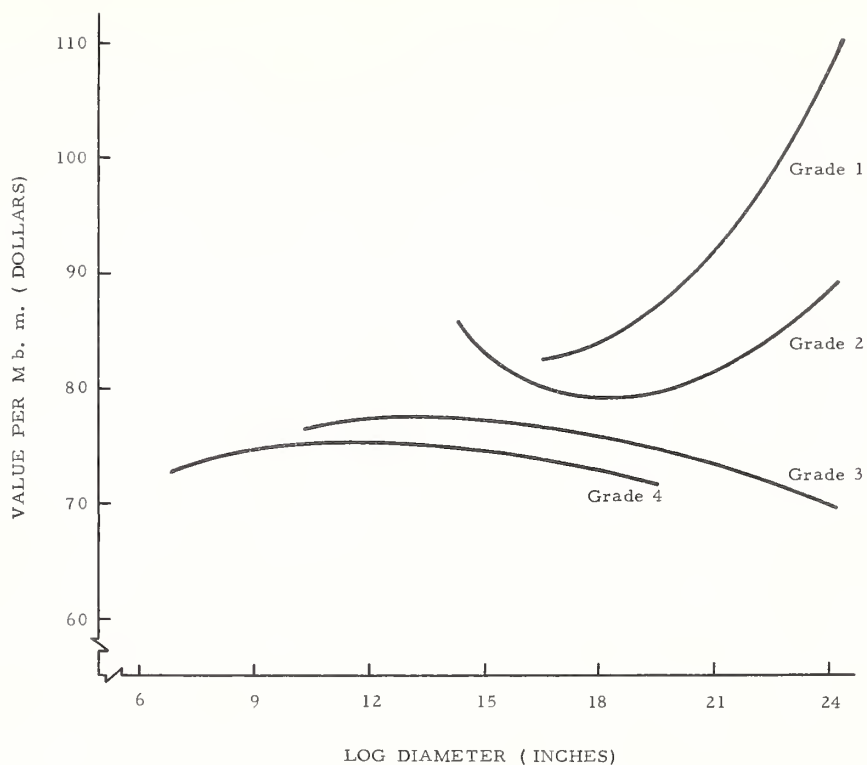


Figure U-5. --Average value per M b.m. dry surfaced lumber, by log grade and diameter class--all 16-foot logs.

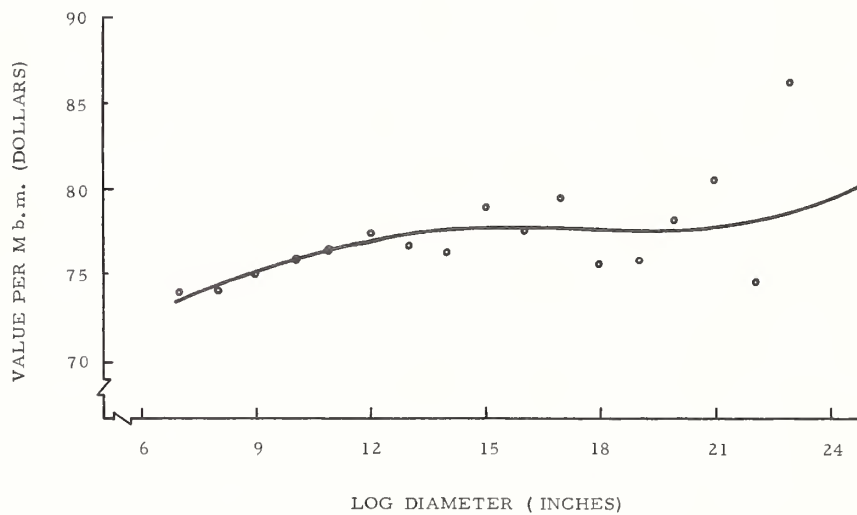


Figure U-6. --Uncurved value per M b.m. dry surfaced lumber, combined log grades--all 16-foot logs.

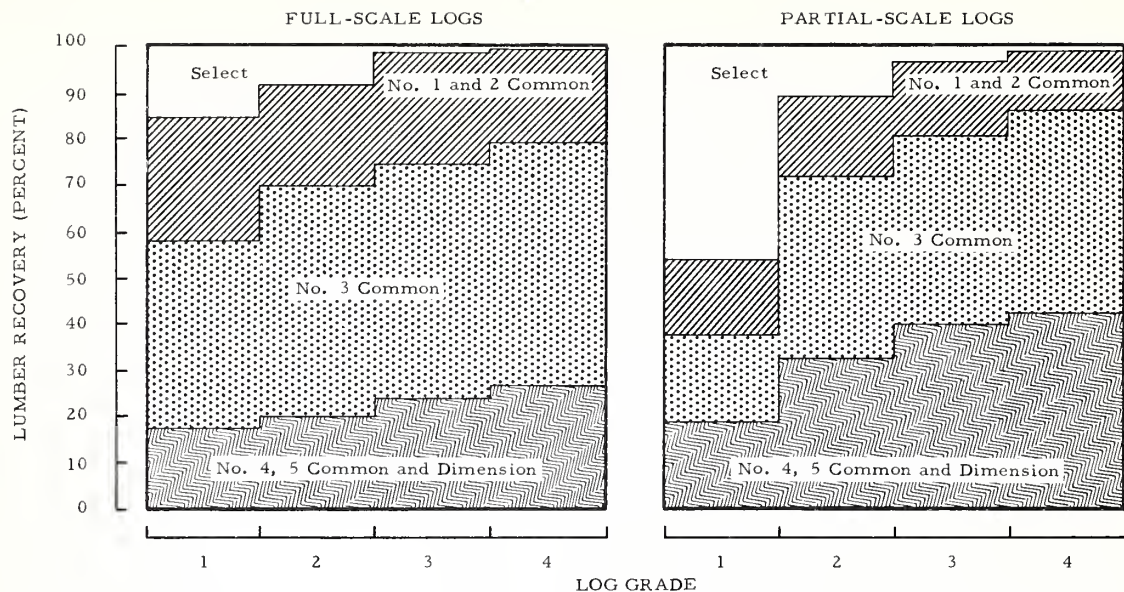


Figure U-7. --Lumber grade recovery, dry surfaced basis, by log grade -- 16-foot logs.

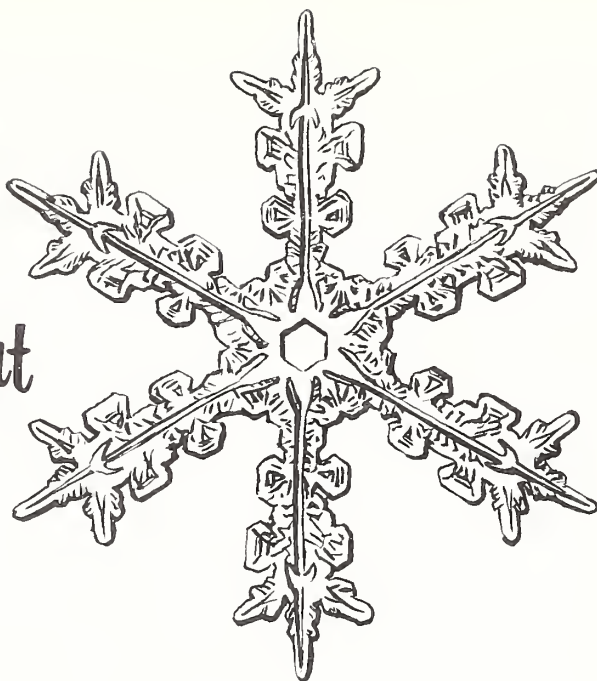
Heart rot major cause of scale deduction in Engelmann spruce logs studied

Western red rot (heart rot) was the principal defect encountered in the 672 logs studied. It made up 44 percent of the total cull. Sweep and crook ranked second in importance, making up 29 percent of the loss. Table U-1 shows the gross scale deduction by defect type and log position.

Table U-1. --Gross scale deductions by defect type and log position (Basis: defect data from 672 logs)

Defect type	Log position				Proportion of total defect
	Butt	Middle	Top	All	
	Percent of gross scale				Percent
Heart rot	3.4	1.8	0	2.0	44.4
Sap rot	.9	.4	0	.5	11.1
Check or split	.3	.2	0	.3	6.7
Sweep or crook	2.4	.8	2.3	1.3	28.9
Shake	.4	.4	0	.4	8.9
Total	7.4	3.6	2.3	4.5	100.0

Watershed Management Research



Forest management and water yield in Arizona

The influence of changes in plant cover upon streamflow from Arizona watersheds is of increasing interest. Fortunately, answers to some questions are coming now from watershed experiments on the Sierra Ancha Experimental Forest about 50 miles north of Globe, Arizona. Gaging stations were established on Workman Creek in 1938 to measure streamflow from an area covered by a forest of ponderosa pine, Douglas-fir, white fir, and Gambel oak. Elevations are between 6,590 and 7,724 feet for the bowl-like basin that drains to the west. This basin is divided into three watersheds, each with a perennial stream. The North Fork watershed contains 248 acres, the Middle Fork 251 acres, and the South Fork 318 acres.

Average annual precipitation on the three watersheds is 32 inches. The maximum amount of 53 inches was received in the 1940-41 water year. The driest water year was 1954-55, with a total precipitation of 20 inches. Streamflow for the pretreatment period averaged about 3.3 inches annually.

In 1953, a study of the results of changes in plant cover on these watersheds was started in cooperation with the Salt River Valley Water Users' Association. The effect of managing for high-quality timber production is being tested on South Fork. The Middle Fork serves as a control. On the North Fork, the forest on the moist site has been removed and that area planted to grass.

On the South Fork, the first cycle of timber cutting began in 1953 and was completed in 1956. About one-half of the merchantable timber was removed. Cutting was planned to favor growth of ponderosa pine and the most vigorous and healthy trees were reserved. In addition to harvesting merchantable trees, the following stand-improvement work was done: (1) unmerchantable ponderosa pine infested with dwarfmistletoe was poisoned; (2) hardwood trees on pine sites were poisoned; as were (3) white fir and hardwood trees that were overtopping pine trees in transition zones between pine and fir areas. In July 1957, a forest fire burned 60 acres in the upper southeast part of the watershed. This fire killed many pine trees. The harvest cut, stand improvement, road construction, and forest fire reduced the basal area of the forest cover by 46 percent. Streamflow has increased only slightly, if at all, as a result of the changes in the forest on South Fork. There has been an apparent increase of less than 0.10 area-inch, or about 3 percent for the years since treatment. This quantity is too small to be statistically significant. There is a tendency for a larger increase in wet years. The dry years since treatment have probably reduced the effect on runoff. More years of record will be necessary for definite conclusions, but for the present the inference is that single-tree-selection silviculture followed by intensive stand-improvement practices will have little effect on water yield from Arizona watersheds.

The area burned by the forest fire suffered heavy erosion. The first storm after the fire was one of the most intense ever recorded at Workman Creek. Total rainfall was almost 4 inches in a 4-hour period. About 40,000 cubic feet of soil was moved from the 60-acre burned area. Forty-three percent of this reached the channel and weir pond and the remainder was deposited on fairly level areas outside the burn. This erosion is perhaps near the maximum to be expected in Arizona from a single storm on the usual rather gentle topography found in the pine type.

On the North Fork watershed the 80 acres of moist site forest composed largely of white fir and Douglas-fir was cleared during September and October 1958 (fig. W-1). The boundary of the cleared area generally coincided with a topographic break between the incised stream channel and the more level upland areas. Where this break was not present, the area was cleared wherever white fir and Douglas-fir composed more than 50 percent of the trees 4 inches and larger.

Logs were cut from trees 10 inches d.b.h. and larger, and hauled from the area. Remaining material was pushed into windrows and burned. A mixture of slender wheatgrass, Kentucky bluegrass, and Orchardgrass was then sown. Redtop was planted along the stream channels. A good catch of grass was obtained. The production at the end of the first season was 500 pounds per acre.

The first year after treatment was dry. Streamflow was 1.4 inches compared with an estimated flow of 0.9 inch had there been no treatment. The next year was above normal in runoff. Actual flow was 6.4 inches compared with an estimated flow of 4.4 inches. The first-year increase of 0.5 inch was not large enough for statistical significance. The second-year increase of 2.0 inches is statistically significant.

Again, more years are required to finally assess the results of this treatment. It is interesting that the proportion of timber removed is less on the North Fork, but that removal was concentrated on a smaller area and on the moist site.

The final result will help in designing systems of management for efficient water yield. Perhaps it will be possible to obtain a large proportion of the potential increase to water yield by special treatment of only a selected part of a watershed.



Figure W-1. --North Fork of Workman Creek after clearing of white fir and Douglas-fir from an 80-acre area along the stream. Merchantable stand averaged about 13 M b. m. per acre. The cleared area was formerly in forest cover. It now contains a good stand of perennial grass.

Timber harvest in Colorado increases streamflow

The snowpack and its forest environment has been a subject of study at the Fraser Experimental Forest in Colorado for 20 years. Early studies conducted on small plots formed the basis for large watershed experiments to determine the influence of (1) timber harvesting on snow accumulation and (2) melt on resultant streamflow.

Streamflow records have been maintained on Fool Creek, a 714-acre watershed, and East St. Louis Creek, a contiguous watershed of 2,000 acres. From 1943 to 1954 streamflow records were compared between these watersheds so that the seasonal flow of one watershed could be predicted from the other.

At the end of this calibration period it was decided to harvest 278 acres of the 550 acres of merchantable 300-year-old lodgepole pine and spruce-fir timber from the Fool Creek watershed. The silvicultural system used was clear cutting in alternate strips varying in size from 66 to 400 feet in width (fig. W-2). No cutting was done along the main stream channel for a distance of 90 feet on each side of the stream. Five miles of main-haul contour roads, and 8 miles of spur roads were constructed prior to logging. The total volume of timber removed from the strips was 3.5 million board feet. Of this, saw logs made up 62 percent of the cut, poles 28 percent, and posts and pulp the remainder. Road construction was completed by 1951; logging began in 1954 and ended in 1956.



Figure W-2. --Alternate clear-cut strips on Fool Creek watershed at the Fraser Experimental Forest in Colorado. The timber harvest removed all trees larger than 4 inches d.b.h. from 39 percent of the watershed. This timber harvest has increased water yield.

What happened to streamflow as a result of this timber harvest? We have five full posttreatment years to answer this question. For each of these years, the excess of actual water yield over that predicted from the comparison with the untreated watershed is shown below:

<u>Years</u>	<u>Predicted Yield</u> - - - - -	<u>Actual Yield</u> (Area inches) - - - - -	<u>Difference</u>
1957	19.6	23.0	3.4
1958	11.4	13.5	2.1
1959	10.5	13.6	3.1
1960	11.1	14.9	3.8
1961	8.8	10.9	2.1

Most of the increase in yield has occurred during the spring freshet period of May and June, but there has also been a small increase in the summer and early fall months. The early rise of Fool Creek is rapid and the spring peak has been higher than it would have been had the timber not been cut.

As is typical of streams from high elevations in Colorado, peak rates of runoff are comparatively low even after treatment. The maximum instantaneous peak runoff from Fool Creek to date is less than 22 cubic feet per second per square mile (c.s.m.). Because of the moderate runoff rate, few intense summer storms, rocky channels, and coarse-textured soils, sediment yield from Fool Creek is low. A basin at the foot of the watershed has trapped only 1.5 cubic feet of sediment (wet volume) per acre of watershed per year.

Chaparral watersheds in Arizona changed by wildfire

On three chaparral watersheds near Roosevelt, Arizona, streamflow, sediment, and precipitation have been measured since 1956. These measurements are part of a cooperative effort by the Salt River Valley Water Users' Association, Arizona Fish and Game Department, and the U. S. Forest Service. All three watersheds were burned over by a large wildfire in June 1959.

Following the fire it was decided to determine changes in water and sediment yield associated with different ways of managing the plant cover. One watershed was allowed to revegetate naturally; a second one was seeded to a mixture of lovegrasses; while the third was seeded to lovegrasses and is being sprayed annually with 2, 4, 5-T to hold back growth of brush species. Spraying is done in cooperation with the U. S. Agricultural Research Service.

Fall 1960 and 1961 measurements show natural sprouting of chaparral (mostly shrub live oak, mountain mahogany, sugar sumac, skunkbush, and desert ceanothus) reached about one-third its prefire density (watershed D). Forbs (principally annual morning glory) and grasses (mainly longtongue bluegrass) increased slightly but exhibited a total basal area cover of less than 3 percent. Crown growth of shrub species was substantially inhibited on the sprayed watershed C when compared with the control watershed D. Average stem length of sprayed shrub live oak was reduced to 21 inches as compared with 30 inches on the control watershed.

Recovery of vegetation, based on vertical crown projection of shrubs and forbs and on basal area of grasses, was as follows:

	<u>Shrubs</u>	<u>Forbs</u>	<u>Grasses</u>
Watershed C (brush sprayed 1960, 1961)	- - - -	(Percent)	- - - -
1958	72.9	0.35	0.41
1959 (burned in June; measured in Oct.)	7.0	.76	1.52
1960	8.5	6.3	.99
1961	7.5	8.6	3.9
Watershed D (brush not sprayed)			
1958	70.2	.76	1.52
1959 (burned in June; measured in Oct.)	7.0	17.0	.28
1960	21.4	9.1	1.5
1961	23.5	7.7	2.4

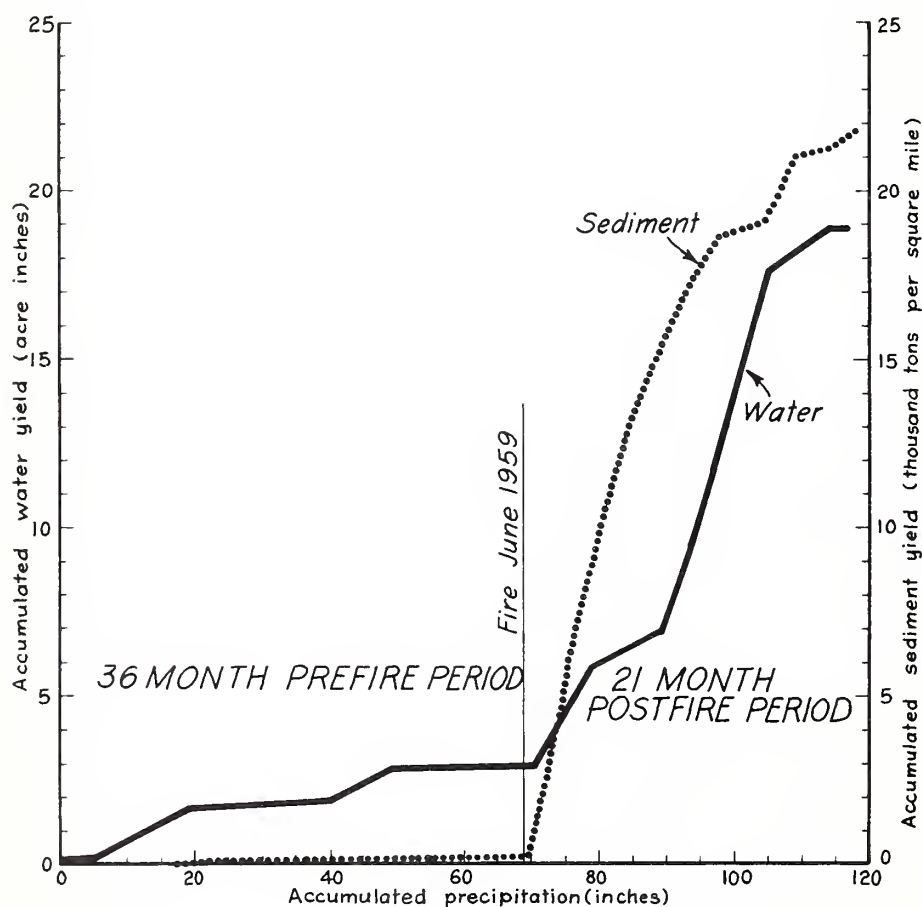


Figure W-3. --Relation between accumulated precipitation and accumulated water and sediment yield, watershed C, Three-Bar experimental watershed, Arizona. Prefire precipitation amounted to 67 inches, runoff 3 inches, and total sediment yield 50 tons per square mile. Postfire-period precipitation amounted to 53 inches, runoff 16 inches, and 22,000 tons per square mile.

Water and sediment yields increased on all watersheds following the fire. Both watersheds C and D maintained a small but continuous flow of water until the summer of 1961. At that time the control watershed ceased flow during the midday, but the sprayed watershed maintained a continuous flow. Figure W-3 shows the relation between accumulated precipitation and accumulated water and sediment yield on the sprayed watershed.

Effect of thinning on water
use by ponderosa pine

To learn how thinning influenced the amount of water used by a ponderosa pine stand, soil moisture and precipitation were measured on plots in the Black Hills of South Dakota. The natural stand is 70 years old and has 2,335 trees per acre with an average d.b.h. of 3.3 inches. On the thinned plot, there are 435 trees per acre with a basal area of 80 square feet.

At the beginning of the growing season there is more moisture in the soil of the thinned plot probably because of less interception. Perhaps because of this higher moisture content the rate of water use is higher on the thinned plot. In the rather dry seasons of 1959 and 1960, an average of 1.8 inches more water was used on the thinned plot. In each year, however, there is also more soil moisture present in the fall under the thinned stand.

A conclusion is that in the Black Hills area thinning will result in increased soil moisture, which should benefit tree growth, but only in extremely wet years will thinning result in more recharge of ground water.

Timothy and sweetclover establish
rapidly after fire in ponderosa
pine forest, Black Hills

The 4,500 acres of ponderosa pine forest that burned around Deadwood, South Dakota, in September 1959, were seeded by helicopter in April 1960, to a grass-legume mixture. The five seeded species accounted for 46 percent of the vegetation on four transects that sampled burned pine stands. Timothy and yellow sweetclover quickly became established and grew rapidly to provide almost all of the cover attributable to seeded species. Kentucky bluegrass plants when present were small, inconspicuous, and overtopped by the much more vigorous timothy plants. Smooth brome grass and Madison vetch, the remaining two seeded species, contributed little to the vegetative cover.

Native vegetation including annuals, perennials, and resprouting shrubs provided 54 percent of the cover for the areas sampled in the burned pine forest. Two annual forbs--Carolina geranium and dragonhead--accounted for most of the vegetal cover. Oregon grape quickly resprouted and was a common species on the fine-textured clay-loam soils.

Runoff on Deadwood
Burn in Black Hills



Figure W-4. --One of the sixteen 1-milacre runoff plots installed in early summer on the 1959 Deadwood Burn in the Black Hills. Plots were on loam and clay loam soils, on both north- and southwest-facing slopes comparing relatively dense with sparse cover conditions. This figure illustrates a plot in dense cover on a southwest slope where water yield was 0.46 inch for summer storm runoff (August 5 to September 30), and 1.82 inches runoff from snowmelt on frozen ground (October 1 to April 1). The cover is mainly timothy, one of the mixture of five species broadcast by helicopter soon after the burn.

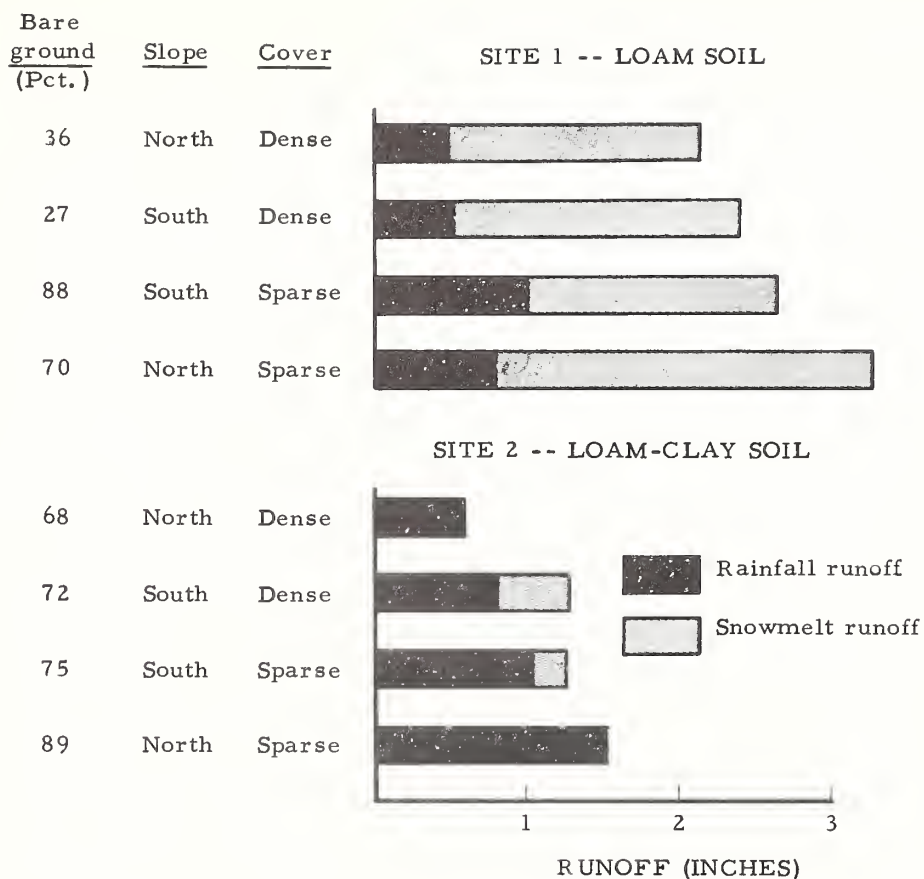


Figure W-5. --Runoff from plots, aspect, soil texture, and vegetative cover on the Deadwood Burn in the Black Hills--rainfall runoff for the period August 5 to September 30, 1959, and snowmelt runoff for the period October 1, 1960, to April 1, 1961.

Soil piping under study in New Mexico

The part "soil piping," a form of subterranean erosion, plays in the continuing process of erosion in the Southwest is being studied in cooperation with the U. S. Bureau of Land Management.

The susceptibility of certain shale and sandstone formations, and soils derived therefrom, to soil piping has aided the rapid extension of the network of arroyos and gullies in the Southwest. In the Rio Puerco in New Mexico, the damaging effects of soil piping are readily observed (figs. W-6, W-7, W-8, W-9).



Figure W-6. --The first step in erosion caused by soil piping comes when cracks develop in the soil surface. Soil cracks develop in the soil or parent material because of the expansion and contraction that accompanies alternate wetting and drying. Soil cracking is most pronounced on bare sediment deposits (Menafee shale origin) as illustrated here.



Figure W-7. --Soil-pipe openings may develop when surface runoff water enters soil cracks caused by drying, flows into holes dug by burrowing animals, or collects in small or large depressions. Soil-pipe openings developed after runoff water collected in this pit located in Mancos shale parent material.

Figure W-8. --Soil cracks in gully sidewalls provide channels for water movement from land slopes to the gully floor. Water flowing through these cracks in soil or fissures in rock causes subterranean erosion and the formation of larger conduits called "pipes." This figure shows a soil pipe opening at the gully floor.



Figure W-9. --Extremely large soil pipes are often formed. Soil is washed out of pipes (tunnels) onto the gully floor. Subsequent caving-in of the soil pipe roofs and sloughing of gully sidewalls results in an extension of the arroyo system.



Plantings for erosion control
successful during wet year

The moist and cool 1961 growing season on the Eastern Slope of the Colorado Front Range has made this a favorable year for the initial testing of plant species for erosion control. Experimental plantings of various species of trees, shrubs, grasses, and forbs are shown in figure W-10. Species showing the greatest promise for survival, growth, and vigor; as well as freedom from damage by insects, diseases, rodents and mechanical means were: sand cherry, a hybrid rose, silverberry, black mustard, hairy vetch, white sweet-clover (evergreen variety), and yellow sweetclover. Continued measurements are necessary to evaluate these species under different growing conditions. This test is part of a large study to determine possible plants for soil stabilization on mountain watersheds.



Figure W-10. --Experimental plantings of grasses and forbs (foreground), trees and shrubs (upper right), for erosion control. The initial growth response of different species is noticeable in this figure.

Cabling juniper
influences runoff

Juniper trees are often cleared by dragging a chain or wire cable between two tractors. When the trees are removed from the ground a small depression or pit is created and tree limbs and branches are brought in direct contact with the ground. This has two hydrologic effects; the pits and limbs impound surface waterflow and the limbs and branches lengthen the flowpath for water that flows around.

Measurements in an area of dense Utah juniper in the Beaver Creek watershed in Arizona showed it is possible that surface flow is reduced 0.09 to 0.27 inch annually (fig. W-11). About 15 percent of the ground surface of the study area was covered by slash piles, and there were 475 lineal feet per acre of trunks of limbs which could dam up surface flow. It is not possible to estimate the total effect of juniper removal on water yield from this single study. Actual watershed tests and other research is now underway to help determine this.

Instrument development important
to watershed research

In the quest for research data, obstacles are often encountered. Surmounting these obstacles is vital to continued progress. One such obstacle may be the inability to make proper measurements of natural phenomena. The lack of an instrument to make such measurements may handicap a research worker.

To enhance watershed investigations three new instruments have been developed. The canopy camera (fig. W-12) was developed to provide a means of studying the relationships between forest canopy density and such things as interception of precipitation, wind, evaporation, radiation, temperature, and tree growth. Density and distribution of the canopy are first put in quantitative terms and then analyzed.

The totalizing radiometer (fig. W-13) was developed to make feasible the taking of a large number of radiation samples simultaneously. Radiometers have been available for some time, but their high cost and/or their need of constant attention made sampling over large forested areas very expensive or impossible.

An instrument for indicating sap movement in a tree is also under development (fig. W-14). This device will help determine when moisture moves in tree stems. Such information is needed to compare seasonal water use by different species and to show how different kinds and sizes of trees respond to environmental factors.



Figure W-11. --When juniper trees are pulled from the ground a pit is left in which surface runoff collects. Water in this pit came from snowmelt.



Figure W-12. --A photograph taken with a newly designed canopy camera. The entire hemisphere is photographed in a single exposure. The horizon forms the perimeter and the zenith the center of the photograph. The camera takes wide-angle, overhead photographs of vegetation canopies, cloud cover, topographic horizons, and similar subjects.

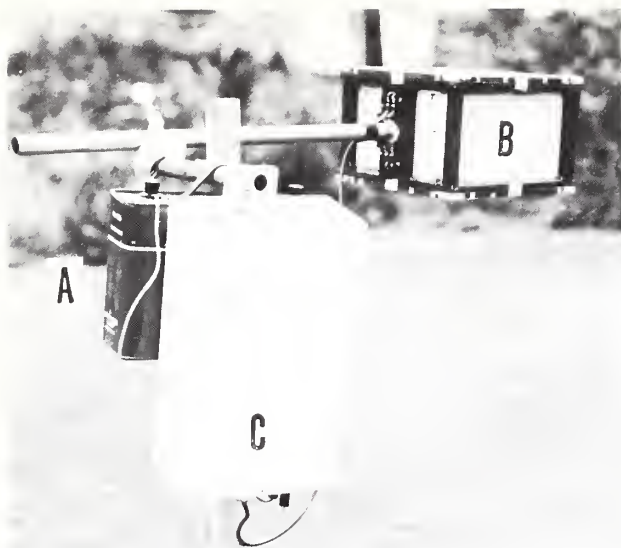


Figure W-13.--

An inexpensive, totalizing, all-wave radiometer. The basic components making up the radiometer are: A, the 6-volt power source, B, the sensing head, and C, the totalizer counter. Radiation from the sun and sky provide much of the energy for melting snow and the evaporation of soil moisture. Forest vegetation, topographic features, and surface conditions strongly affect the amount of energy that becomes available as heat to dry soil or melt snow. This inexpensive instrument makes it possible to measure this energy.



Figure W-14.--A newly developed instrument to measure moisture flow in stems. A pulse of heat is inserted into the tree through the center probe at left. The meter at right times the rate of movement of the heat pulse both upstream and downstream from the center heat probe. The measured time differences are used in appropriate formulas to solve for sap velocities. Use of this meter makes possible the detection of very low sap velocities. This information will be helpful in better understanding the physiology of different forest brush and tree species.



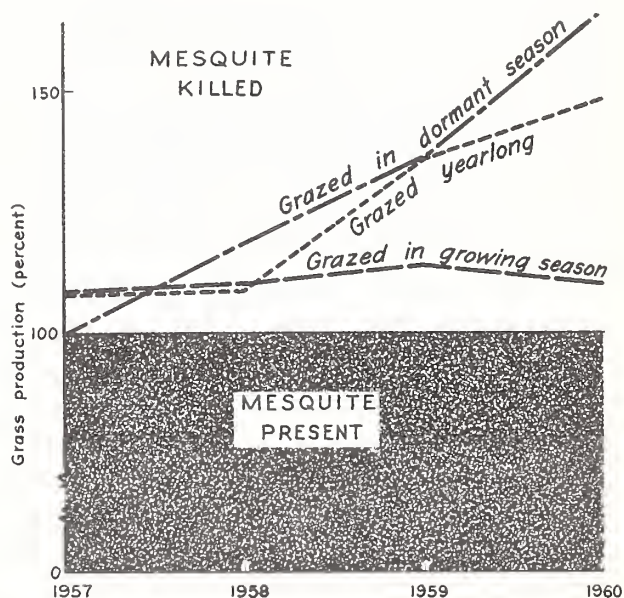
Range Management and Wildlife Habitat Research

Grass production influenced
by time of grazing

Three years after mesquite (*Prosopis juliflora* var. *velutina*) was killed on plots on the Santa Rita Experimental Range in southern Arizona, production of perennial grasses had increased 70 percent more on ranges grazed only during the late fall-winter-early spring season than on check plots. At that time the perennial grasses are largely dormant (fig. R-1). In contrast perennial grasses increased 35 percent on plots grazed year-long but not at all on plots grazed only during the growing season. All pastures in which these plots were located were grazed to approximately 40 percent herbage removal of the perennial grasses.

Figure R-1. --

Production of
perennial grass
herbage following
mesquite control,
with different
seasons of grazing.



On the average best response to mesquite control was on soils underlain with a clayey subsoil (fig. R-2). Production under these conditions on the average increased 62 percent in contrast with only 23 percent where the subsoil was sandy.



Figure R-2. --A, Rangeland infested with mesquite; B, the same area in 1959, 2 years after mesquite had been killed. The site has a clayey subsoil that seems to favor growth of perennial grasses.

These results suggest that benefits of mesquite control may be nullified if grazing is confined to the growing season. Best grass response may be expected on areas with clayey subsoils and where grazing is confined to the dormant period of the grasses.

Shrub cover increasing
on Mingus Mountain burn

Live plant material on Mingus Mountain in central Arizona has increased to 7,100 pounds per acre, green weight, five growing seasons after a wildfire completely denuded the chaparral site. Shrubs have continued to increase in dominance and now account for 91 percent of the plant composition (fig. R-3). Shrub live oak (*Quercus turbinella*) is the major component. Forbs, which produced 19 percent of the total plant material on the area in 1958, contributed only 7 percent in 1960. The decline was largely due to death loss of Palmer penstemon (*Penstemon palmeri*). Perennial grasses, which have increased slowly but steadily since the fire, produced 175 pounds per acre in 1960. Weeping lovegrass (*Eragrostis curvula*) and crested wheatgrass (*Agropyron cristatum*), seeded after the fire, produced about 27 percent of the grass herbage. Side-oats grama (*Bouteloua curtipendula*) has continued to be the most prominent native grass on the burned area.

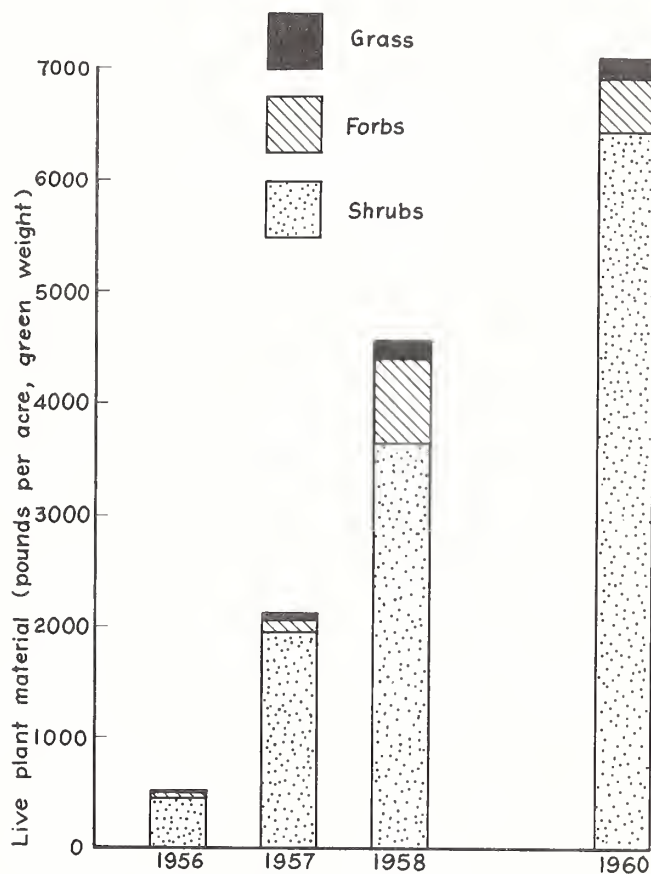


Figure R-3. --Plant material produced on a chaparral site denuded by the Mingus Mountain fire in 1956.

Small stumps of alligator juniper
sprout more readily than large ones

On the Beaver Creek watersheds south of Flagstaff, Arizona, stumps of alligator juniper (*Juniperus deppeana*) less than 6 inches in diameter sprouted more readily than larger ones, as shown below.

<u>Stump diameter</u> (Inches)	<u>Stumps observed</u> (Number)	<u>Stumps with sprouts</u>	
		(Number)	(Percent)
1- 6	156	140	90
7-12	27	18	67
13-30	37	22	59
31-48	2	0	0

Height of stumps, on the other hand, apparently did not affect sprouting ability of trees cut in August 1957. Of the 30 trees cut to a 4-foot stump, 28 had produced sprouts 1 year later. Cutting to a 4-foot stump in winter was not tested.

In another study, season of cutting had only slight effect on sprouting ability of trees less than 4 inches in diameter. Although the percentage of trees that eventually sprouted was about the same for all cutting dates, sprouts from trees cut in October or June developed more slowly than those from trees cut in August, January, or April.

Alligator juniper has three types of sprouts: epicormic (from trunk), basal, and root (fig. R-4).



A

Figure R-4. --Three types of sprouts produced by alligator juniper: A, Root sprout; B, Basal sprout; C, From trunk.



Alligator juniper can be controlled with chemicals

Because of its ability to sprout from roots, root crown, and trunk, alligator juniper has defied most attempts at mechanical control. Recently, however, excellent control of basal sprouts was obtained in northern Arizona by spraying stumps with polychlorobenzoic acid (PBA). The solution was applied at a concentration of 8 pounds acid per 100 gallons of diesel fuel until runoff began. Spring and winter applications gave the best results. Limited control resulted from application of 2,4,5-T, silvex, and amitrole. Pellets of fenuron applied to the soil at the base of stumps also gave encouraging results. These tests were made in a cooperative study with the U. S. Agricultural Research Service near Flagstaff. Control of this weed-tree in many areas of Arizona and New Mexico would encourage growth of more valuable trees and forage plants.

Growth characteristics of grasses of pinyon-juniper range

Cool-season grasses in the pinyon-juniper type in Arizona reach their peak height between May 18 and June 23, and generally produce some green material all year. Warm-season grasses are green only during the spring, summer, and fall, and reach their peak height between September 11 and September 21. These dates are based on phenological measurements taken from 1957 to 1960. Time of height growth and length of period when some green forage is available for grass species of the pinyon-juniper type are shown below:

<u>Season and species</u>	<u>Average date of peak leaf height</u>	<u>Average peak height</u> (Inches)	<u>Green leaves more than 2 inches high</u>
COOL-SEASON GRASSES:			
Muttongrass (<u>Poa fendleriana</u>)	May 18	16	Yearlong
Junegrass (<u>Koeleria cristata</u>)	June 18	14	Yearlong
Bottlebrush squirreltail (<u>Sitanion hystrix</u>)	June 22	14	Yearlong
Western wheatgrass (<u>Agropyron smithii</u>)	June 23	13	March 20-December 1
Average	June 13		
WARM-SEASON GRASSES:			
Galleta (<u>Hilaria jamesii</u>)	September 11	15	April 20-November 1
Blue grama (<u>Bouteloua gracilis</u>)	September 12	10	May 1-November 1
Black grama (<u>Bouteloua eriopoda</u>)	September 15	17	May 1-October 10
Spike muhly (<u>Muhlenbergia wrightii</u>)	September 16	13	May 1-December 1
Black dropseed (<u>Sporobolus interruptus</u>)	September 16	18	April 1-November 10
Side-oats grama (<u>Bouteloua curtipendula</u>)	September 21	22	March 20-December 1
Average	September 15		

With a good mixture of grasses, a pinyon-juniper range should supply ample green forage from April 1 to September 30, and some green feed would be available all winter. Grazing systems adapted to the type should allow occasional rest for both cool-season and warm-season grasses. Since two distinct growing seasons are represented, forage production measurements should be taken in June for cool-season species and in September for warm-season species.

Lambs gain most on lightly
grazed crested wheatgrass

Lambs in lightly stocked crested wheatgrass paddocks, used as spring lambing range, at Tank Canyon in northern New Mexico gained on the average about 3 pounds more than those in heavily stocked paddocks from 1957 to 1959. In general, gains were inversely related to grazing intensity (table R-1). In 1959 when forage conditions were poor and the grazing season short, the lambs gained less than in other years. This was true not only for seasonal gains but for daily gains also.

Table R-1. --Average gain of lambs on crested wheatgrass
at Tank Canyon, New Mexico, during May and June.

Average use of crested wheatgrass (in percent)	Average gain			
	1957	1958	1959	3-year period
	Pounds			
39	26.3	25.4	13.2	21.6
53	24.4	23.7	11.3	19.8
72	24.0	24.8	9.9	19.6
84	22.2	21.6	12.7	18.8



Figure R-5. --Lambs were weighed within 1 day after birth and again when removed from crested wheatgrass paddocks in northern New Mexico.

Crested wheatgrass yields fluctuate with rainfall

Most of the variation in yield of crested wheatgrass on lambing range in northern New Mexico from 1957 to 1960 was due to differences in precipitation before and during the growing season (fig. R-6). An average yield on 399 pounds per acre, air-dry, was obtained under 4-inch rainfall from January through May, compared with 1,565 pounds under rainfall of 9.62 inches. These records are from sheep paddocks at Tank Canyon in which crested wheatgrass was grazed at different intensities.

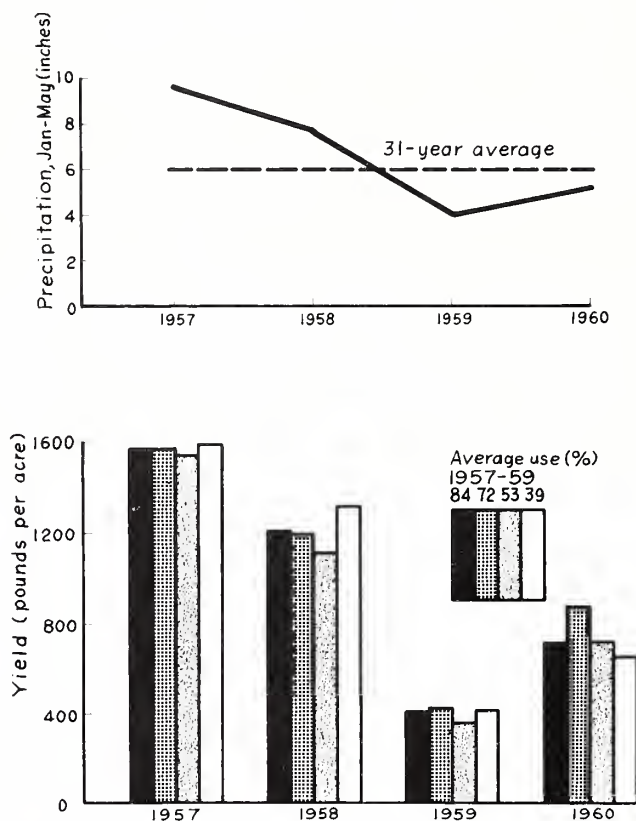


Figure R-6. --Crested wheatgrass yields as related to antecedent rainfall and four intensities of sheep grazing at Tank Canyon, New Mexico, 1957-60.

Different levels of grazing were achieved by placing different numbers of pregnant ewes in twelve 5-acre paddocks. The ewes lambed in 12 paddocks and grazed for 36 to 53 days in May and June from 1957 through 1959.

Herbage yields apparently were little affected by grazing intensity during the study period. However, the test period was for only 3 years. Production in 1960 following 3 years of light (39 percent) use averaged 646 pounds compared with 711 pounds where use averaged 84 percent. These are reductions of 59 and 55 percent, respectively, from yields recorded in 1957. Production was measured by clipping to ground level and weighing herbage from small fenced plots (fig. R-7).



Figure R-7. --Production of crested wheatgrass was measured by harvesting small fenced plots. This area, in one of the heavily grazed paddocks at Tank Canyon, New Mexico, was photographed during a dry year, May 28, 1959.

Shrubs damaged on heavily
grazed lambing range

Mortality of shrubs in crested wheatgrass stands at Tank Canyon in northern New Mexico was, in general, proportional to the intensity of use of the wheatgrass (fig. R-8). After 3 years, 16 percent of big sagebrush (Artemisia tridentata) plants in the most heavily grazed paddocks were dead compared with 3 percent in lightly grazed areas. Silver sagebrush (A. cana) and rubber rabbitbrush (Chrysothamnus nauseosus) also were damaged, though somewhat less.

Utilization of crested wheatgrass (Percent)	Dead plants		
	Big sagebrush (Percent)	Silver sagebrush (Percent)	Rubber rabbitbrush (Percent)
84	16.0	10.5	6.2
72	14.1	11.7	9.5
53	9.4	8.6	4.1
39	2.9	4.4	1.0
0	3.8	3.6	0



Figure R-8. --Silver sagebrush was browsed more severely where use of crested wheatgrass for 3 years averaged 72 percent (A) than where use averaged 50 percent (B).

These results suggest that scattered shrubs in crested wheatgrass stands might be held in check by heavy spring grazing by sheep. Big and silver sagebrush apparently would be retarded more than rabbitbrush.

Vigor of crested wheatgrass declines
on heavily used lambing range

Another finding from the Tank Canyon study in northern New Mexico was that crested wheatgrass plants tend to become smaller and lose vigor under heavy use on lambing range (fig. R-9). At the beginning of the study in 1957 average basal diameters under all treatments ranged from 3.3 to 3.6 inches. When remeasured in 1960, diameters averaged 1.8 to 2.2 inches (table R-2). In heavily grazed paddocks the decrease amounted to 1.8 inches compared with 1.1 inches in lightly grazed areas. Leaf lengths showed a similar trend. Culm heights were similar in all except the heaviest grazed paddocks where they averaged about 1 inch shorter than the others.

Table R-2. --Size of individual crested wheatgrass plants
in Tank Canyon paddocks, New Mexico

Average utilization (Percent)	:	:	Basal diameter	:	Leaf length	:	Culm length
:	Year	:	:	:	:	:	:
- - - - - Inches - - - - -							
84	1957		3.6		14.2		20.3
	1960		1.8		6.1		9.9
72	1957		3.4		13.3		20.0
	1960		1.9		7.0		11.1
53	1957		3.6		14.5		21.0
	1960		2.2		7.1		10.8
39	1957		3.3		14.3		20.4
	1960		2.2		7.4		10.9

Further evidence of the effect of different grazing intensities on plant vigor was the number of plants on which more than three-fourths of the crown was dead at the end of the 3-year study. From an average of 8 such plants per 100 square feet on ungrazed areas, the number increased with grazing intensity to a maximum of 16 on the most heavily grazed paddocks. This may explain in part why crested wheatgrass plants became smaller under heavy grazing. Fragmentation, the breakdown of large plants into a number of smaller ones under grazing, was observed here as well as in earlier studies on cattle ranges in northern New Mexico.

Young, well-established plants of crested wheatgrass were most abundant in paddocks that had been grazed at light to medium rates. On ungrazed areas they were only slightly more numerous than in paddocks grazed the most heavily. Dead plants, on the other hand, were least abundant on areas protected from grazing. Their number increased with grazing intensity. Most significant,



Figure R-9. --Comparative size and vigor of crested wheatgrass plants after 3 years of different grazing by sheep: A, where use averaged 60 percent; B, where use averaged 88 percent.

perhaps, is the fact that young plants outnumbered dead plants in all except the most heavily grazed paddocks (fig. R-10). Thus, it appears that light or moderate use of lambing range may be more conducive to maintenance of crested wheatgrass stands than no grazing or extremely heavy grazing.

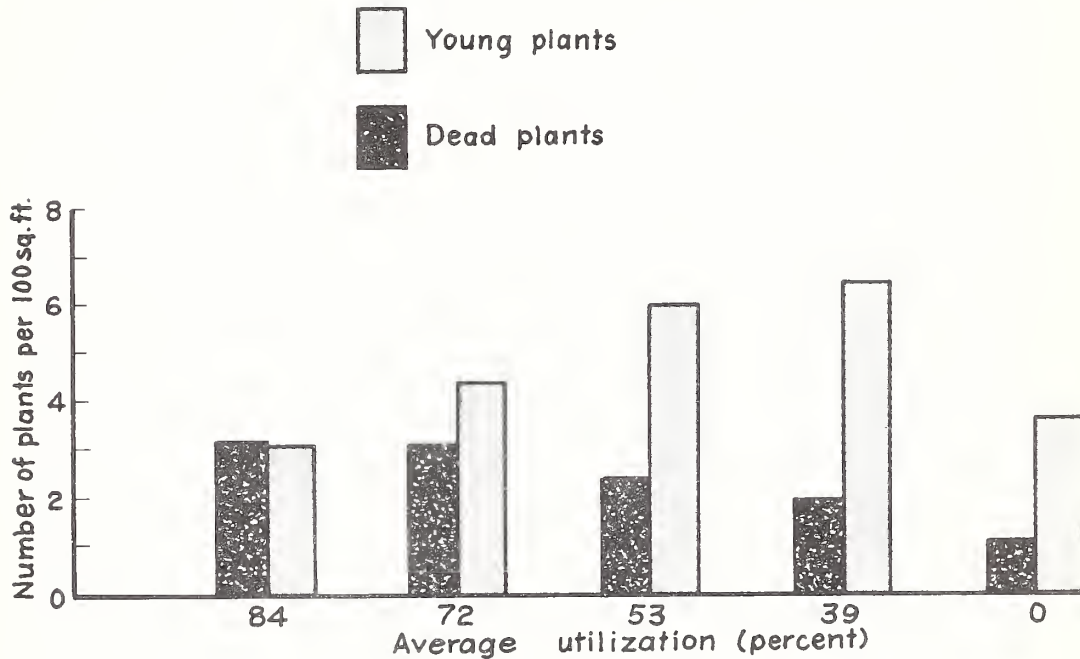


Figure R-10. --Relative abundance of young plants and dead plants of crested wheatgrass in paddocks that had been grazed at different intensities by sheep for 3 years. Tank Canyon, New Mexico, 1960.

Beef-producing ability of
seeded ranges compared

While the most gain per acre was produced by heifers grazing a mixture of crested wheatgrass and smooth brome (*Bromus inermis*), highest average daily gains per head were made in intermediate wheatgrass (*Agropyron intermedium*) pastures in the ponderosa pine type at the Manitou Experimental Forest in Colorado.

Included in the test to determine the relative grazing value of several seeded species were four grasses and a mixture. After the stands were well established, they were grazed by yearling heifers during the spring-summer-fall months for 9 to 11 years. The gains listed below are averages for three intensities of grazing for the entire period.

<u>Species</u>	<u>Length of test (Years)</u>	<u>Gain per acre (Pounds)</u>	<u>Gain per day (Pounds)</u>
Crested wheatgrass	11	59.2	1.67
Smooth brome	11	40.2	1.52
Mixture of crested wheat- grass, smooth brome, and yellow sweetclover	11	71.6	1.81
Intermediate wheatgrass	9	52.3	1.92
Russian wildrye	9	48.8	1.53

Although intermediate wheatgrass produced high daily gains, it did not withstand grazing well. When grazed to a 2-inch stubble, yields declined, resulting in fewer grazing days and less total beef production than from some of the other species.

Of interest is the finding that a mixture of crested wheatgrass, smooth brome, and yellow sweetclover (Melilotus officinalis) produced higher gains, both daily and per acre, than pure stands of either of the grasses alone over the 11-year period. The sweetclover largely disappeared after 2 years and smooth brome gradually was replaced by crested wheatgrass. Even so, the mixture was more productive throughout the study, possibly from the influence of sweetclover.

Russian wildrye (Elymus junceus), though not grazed as intensively as either crested wheatgrass or smooth brome, produced daily gains similar to those from smooth brome.

Because it produced relatively high animal gains and held up well under grazing, crested wheatgrass is recommended as best, among the species tested, for seeding deteriorated ponderosa pine rangelands in eastern Colorado. Also, benefit will be obtained by including yellow sweetclover in mixture.

Livestock prefer certain plants on salt-desert winter range

Salina wildrye (Elymus salinus) is a choice forage plant on Badger Wash in western Colorado although it is not a dominant plant. Indian ricegrass (Oryzopsis hymenoides) also rates high in palatability. However, galleta produces much more forage because it is relatively abundant and receives moderate grazing use. Use of bottlebrush squirreltail is light because it is usually found within the protective cover of spiny shrubs. Cheatgrass brome (Bromus tectorum), though widespread, grows too late in the spring to furnish winter forage.

Among the shrubs, Greenes rabbitbrush (Chrysothamnus greenii) is a major producer of palatable browse. Livestock also seek winterfat (Eurotia lanata), big sagebrush, ephedra (Ephedra spp.), and bud sagebrush (Artemisia spinescens). Very little forage is furnished by the most productive shrub, shadscale saltbush (Atriplex confertifolia), possibly because of its spiny twigs.

Broom snakeweed (Gutierrezia sarothrae) and cottonthorn horsebrush (Tetradymia spinosa) are seldom grazed. Gardner saltbush (Atriplex nuttallii) provides limited forage on the heavier soils.

Relative preference of cattle and sheep for forage species on Badger Wash experimental watersheds, 1956-58, is shown below. Utilization is based on weight of the previous year's growth.

<u>Forage species</u>	<u>Utilization</u> (Percent)	<u>Frequency</u> <u>of occurrence</u> (Percent)
GRASSES:		
Salina wildrye	75	32
Indian ricegrass	46	41
Galleta	32	64
Bottlebrush squirreltail	7	44
Cheatgrass brome	T	74
SHRUBS:		
Winterfat	51	10
Greenes rabbitbrush	38	64
Big sagebrush	36	16
Gardner saltbush	11	48
Broom snakeweed	5	67
Cottonthorn horsebrush	4	20
Shadscale saltbush	4	67

Badger Wash, where this study is located, is a dual-use range grazed by both sheep and cattle from November until mid-May.

Ground cover changes
with gopher control

Where pocket gophers were excluded from Thurber fescue (Festuca thurberi) grassland range on Black Mesa in west-central Colorado, litter and perennial grasses increased substantially in 3 years (fig. R-11). When trapped from eight 1-acre study areas in September 1957, gopher populations averaged 26 per acre. Strict control since then has practically prevented reinvasion of the exclosures.

Bare soil, as measured by the loop-transect method, was exposed on nearly half the ground surface in 1957; in 1960 it comprised less than a quarter of the surface. The reduction in bare soil was caused primarily by an increase in litter, and to a lesser extent by an increase in grasses, mainly Idaho fescue (Festuca idahoensis). Though a buildup of litter might be expected where gopher activity is curtailed, the increase in grass plants has yet to be explained, especially in view of the finding that gophers feed largely on forbs in similar areas.

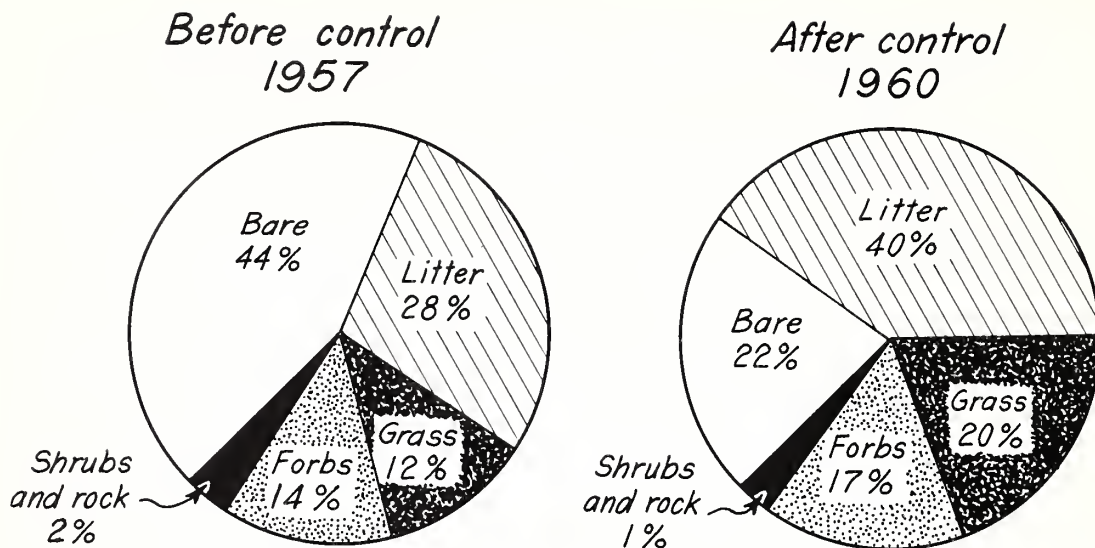


Figure R-11. --Ground cover increased after pocket gophers were controlled in mountain parks, Black Mesa, Colorado.

Gophers prefer forbs
on mountain grasslands

More than 90 percent of the diet of pocket gophers during summer months may consist of forbs. Most of this food consists of leaves and stems obtained aboveground, according to a cooperative study with the U. S. Fish and Wildlife Service on Black Mesa in western Colorado.

Examination of plant material in stomachs of nearly 400 gophers trapped periodically during two summers showed that gophers ate the following:

<u>Kind of plant</u>	<u>Percent of the gopher diet</u>
Aspen fleabane (<u>Erigeron macranthus</u>)	24
Lupines (<u>Lupinus spp.</u>)	15
Hairy goldaster (<u>Chrysopsis villosa</u>)	14
Slenderleaf gilia (<u>Gilia linearis</u>)	11
Aspen peavine (<u>Lathyrus leucanthus</u>)	8
Common dandelion (<u>Taraxacum officinale</u>)	7
Fremont geranium (<u>Geranium fremontii</u>)	5
Other forbs	9
Grasses	6
Shrubs	1
Total	100

Among the gophers examined, no grass whatsoever was found in 38 percent of the stomachs, but forbs were present in all.

Herbage composition of grasslands from which gophers were trapped was 50 percent grass, 42 percent forbs, and 8 percent shrubs. Principal plant species were Idaho fescue, Thurber fescue, Letterman needlegrass (Stipa lettermani), Fremont geranium, hairy goldaster, aspen fleabane, and Parry rabbitbrush (Chrysothamnus parryi).

The limited records available suggest that mountain pocket gophers rely largely on fleshy roots and bulbs of forbs during the winter. Stems of rabbitbrush also are commonly clipped during late fall and winter.

Results of grazing intensity study summarized

The "Effect of grazing intensity on cattle weights and vegetation of the Bighorn experimental pastures" is the title of Bulletin 373 published cooperatively by the University of Wyoming Agricultural Experiment Station in 1961. This bulletin summarizes results of an 8-year cooperative study of the Rocky Mountain Forest and Range Experiment Station and several other agencies.

Six pastures in the Bighorn Mountains were grazed at different intensities by yearling steers during summer months of 1951 to 1958. Plant cover of the pastures consists of a variety of mountain grassland species, of which Idaho fescue and avens (Geum triflorum) are dominant. Annual precipitation averages about 25 inches. The pastures range in size from 83 to 92 acres and contain granitic and sedimentary soils.

Results of the study revealed that optimum use of Idaho fescue, the key forage species on these ranges, is about 40 to 45 percent, based on weight of herbage produced. Under that use fescue maintained production and animal gains averaged 2.2 pounds per day. Lighter use resulted in an increase in production of fescue, smaller animal weight gains per acre, and generally higher gains per animal. Heavier use reduced the vigor and production of Idaho fescue, resulted in higher animal gains per acre, and produced lower gains per animal.

When the study ended, cover of Idaho fescue was somewhat denser on lightly stocked pastures than on heavily stocked pastures. Cover of Sandberg bluegrass (Poa secunda) and canby bluegrass (Poa canbyi), which are generally regarded as less desirable grasses, tended to increase under heavy grazing.

Idaho fescue on granitic soil was found to be more sensitive to grazing than on soils derived from sedimentary rocks. Under light use its production increased more, and under heavy use its production decreased more.

Cattle prefer sagebrush areas sprayed with 2,4-D

Forage plants were grazed more closely where sagebrush had been sprayed with 2,4-D just before the grazing season than where it was not sprayed on the Bighorn National Forest in 1960 (table R-3).

Table R-3. --Forage utilization, in percent of weight removed, the first growing season after controlling sagebrush with 2, 4-D

Species	Shell Creek area		Tensleep area	
	Sprayed	Unsprayed	Sprayed	Unsprayed
	Percent			
Thickspike wheatgrass (<u>Agropyron dasystachyum</u>)	63	36	70	55
Pumpelly brome (<u>Bromus pumpellianus</u>)	69	--	78	80
Idaho fescue (<u>Festuca idahoensis</u>)	50	32	72	52
Bluegrasses (<u>Poa spp.</u>)	56	15	77	49
Subalpine needlegrass (<u>Stipa columbiana</u>)	34	8	50	28
Other grasses	40	10	45	14
Smallwing sedge (<u>Carex microptera</u>)	43	--	58	11
Sedge species (<u>Carex obtusata</u>)	27	2	24	34
Dunhead sedge (<u>Carex phaeocephala</u>)	34	15	35	10

In the Tensleep area thickspike wheatgrass and Idaho fescue, both important forage producers, were grazed 15 to 20 percent more than on contiguous unsprayed areas. On the Shell area differences of 18 to 27 percent were recorded. Although low forage production in 1960 may have contributed to severe grazing of some species, cattle definitely preferred forage on the sprayed areas. Sagebrush cover, which averaged 18 percent, was reduced about 90 percent by spraying.

Herbage moisture useful for predicting crude protein

Crude protein in Kentucky bluegrass (Poa pratensis) and other grasses and sedges in the Black Hills, South Dakota, decreased as moisture content of the plants decreased. In Kentucky bluegrass, crude protein decreased rapidly as moisture content declined from 80 percent to 60 percent of the oven-dry weight, but it decreased relatively little when moisture was less than 60 percent (fig. R-12).

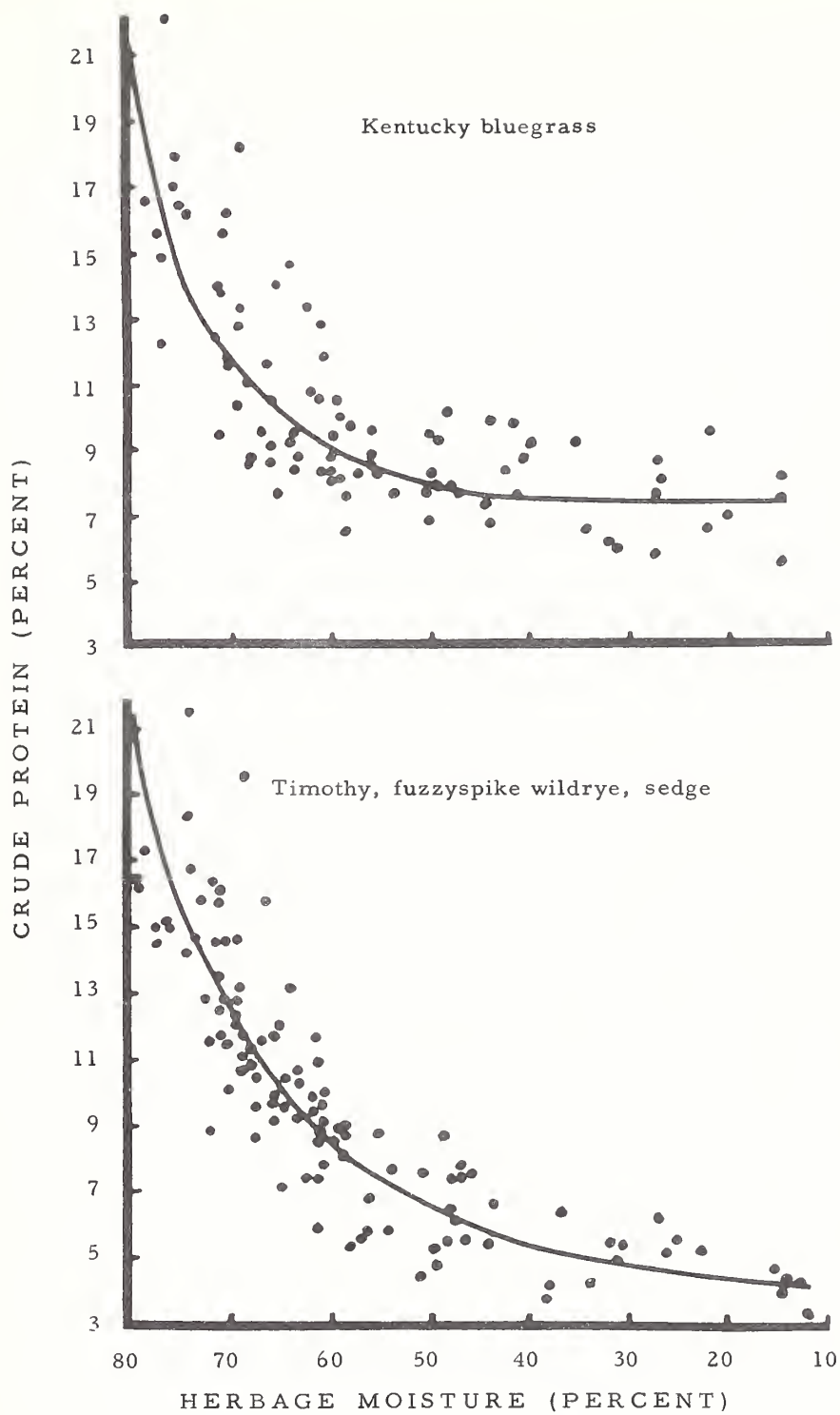


Figure R-12. --Relationship of crude protein to moisture content of several grasses and sedges in the Black Hills.

A similar decline in crude protein at the higher moisture levels was determined for timothy (*Phleum pratense*), fuzzyspike wildrye (*Elymus innovatus*), and sedges. However, in contrast to Kentucky bluegrass, the protein content of those species continued to decrease rather rapidly when moisture content was less than 60 percent.

The moisture-crude protein relationship appears close enough to warrant use of field moisture as a general index of crude protein. This would be advantageous since moisture content is easier and less expensive to determine. Correlation coefficients for the relationship were 0.78 for bluegrass and 0.87 for the other species.

Roughleaf ricegrass, a winter source of protein for wildlife

Roughleaf ricegrass (*Oryzopsis asperifolia*) remains partly green and relatively high in protein throughout the year. In the Black Hills of South Dakota it could be an important source of protein for wildlife during the winter when green forage is relatively scarce. Casual observations indicate that it is grazed both by deer and rabbits. Commonly present in ponderosa pine stands, it produces up to 100 pounds of air-dry herbage per acre.

Near Rapid City, South Dakota, this plant began growth in April or May in 1957 and 1958. Leaves attained a maximum length of more than 12 inches 2 months later, then began to dry from the tips downward (fig. R-13). Though the green portion continued to shorten during fall and winter, it averaged 5 inches long the following spring. A few leaves lived as long as 2 years. Meanwhile, new leaves developed among the older ones.

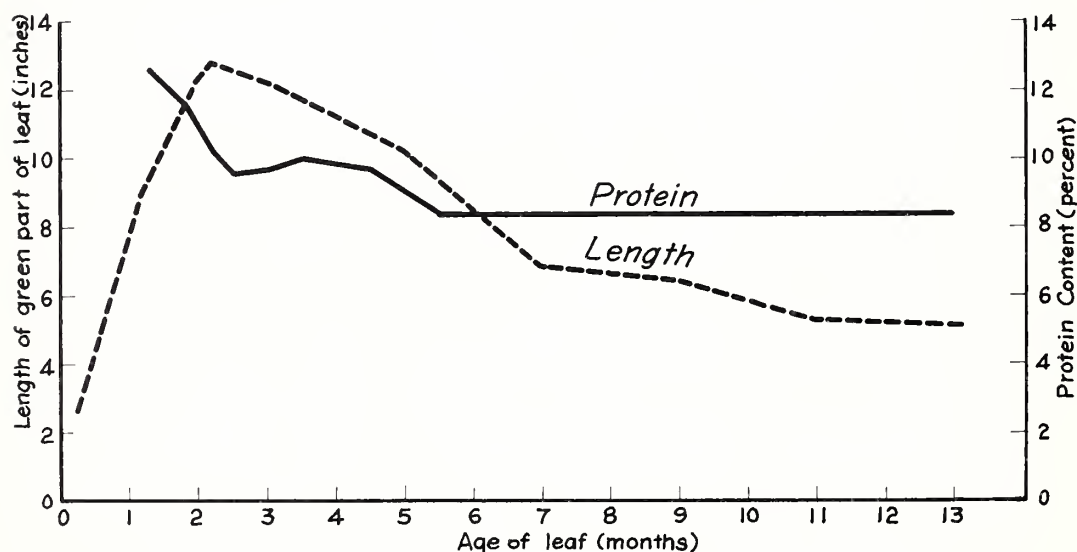


Figure R-13. --Average crude protein content of the green part of ricegrass leaves of various ages in the Black Hills, 1957-58.

Crude protein content of the green part of the leaves ranged from 12.6 percent in young succulent leaves to 8.4 percent in leaves that had overwintered. Because the protein content was the same (8.4 percent) before and after overwintering, it likely remains relatively high throughout the winter.

Bitterbrush grows more rapidly than native browse species in the Black Hills

Three years after planting, seedlings of bitterbrush (Purshia tridentata) were larger than those of several native browse species in the Black Hills. Height growth of all species was greater in the open on an old burn than beneath a ponderosa pine stand as shown below and in figures R-14 and R-15.

	<u>Pine Stand</u> (Inches)	<u>Old Burn</u>
Antelope bitterbrush (<u>Purshia tridentata</u>)	5.5	11.4
Common chokecherry (<u>Prunus virginiana</u>)	3.3	6.1
Pin cherry (<u>Prunus pensylvanica</u>)	1.5	4.8
True mountainmahogany (<u>Cercocarpus montanus</u>)	3.0	4.1

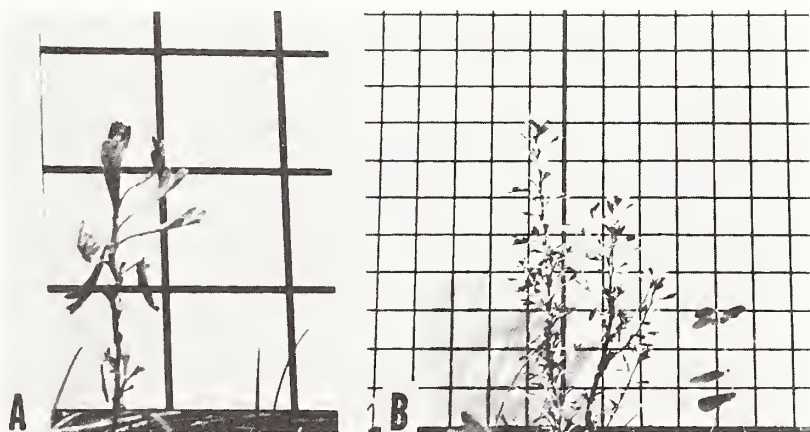


Figure R-14. --Growth of bitterbrush seeded in a ponderosa pine stand in the Black Hills: A, 1-year-old seedlings; B, 3-year-old seedlings. (Grid scale = 1 inch.)



Figure R-15. --Growth of bitterbrush seeded on an old burn in the Black Hills:
A, 1-year-old seedlings; B, 3-year-old seedlings. (Grid scale = 1 inch.)

Soil moisture was slightly higher on the forested site than on the open site throughout the growing season. However, precipitation each year since the initial planting in 1957 has been below the long-time average of 21-22 inches. Both sites are on south-facing slopes with shallow soils.



(In cooperation with the U. S. Fish and Wildlife Service)

Pocket gopher mound counts
used to follow population trends

Beginning with a sharp decline in the fall of 1959, the pocket gopher population has remained low through the fall of 1961 on grazed Thurber fescue grassland parks at the Black Mesa Experimental Area in western Colorado (fig. B-1). Because of this reduction in numbers, damage to soil and vegetation has been light. (figs. B-2 and B-3.)

Population trends have been followed at Black Mesa by "erasing" mounds on permanent plots, then counting new mounds appearing on these plots after a prescribed period of time. The mound counts were made on native range under heavy, moderate, and light grazing treatments. In the first 5 years of grazing treatment, there has been no marked difference between pocket gopher population trends on the ranges subject to various intensities of cattle use (fig. B-1).

The direct cause or causes of the 1959 population crash are not known, but the decline was associated with a lack of young in the population. Pocket gophers were numerous on Black Mesa range in 1957 and 1958 and about 60 percent of the animals were young-of-the-year. When the decline occurred in 1959, there was only about 14 percent young in the fall population.

Montane vole populations not
high on Black Mesa range

The montane vole, a small mammal frequently considered to be a competitor for range forage, particularly in years of high population, has been low in numbers at Black Mesa (table B-1).

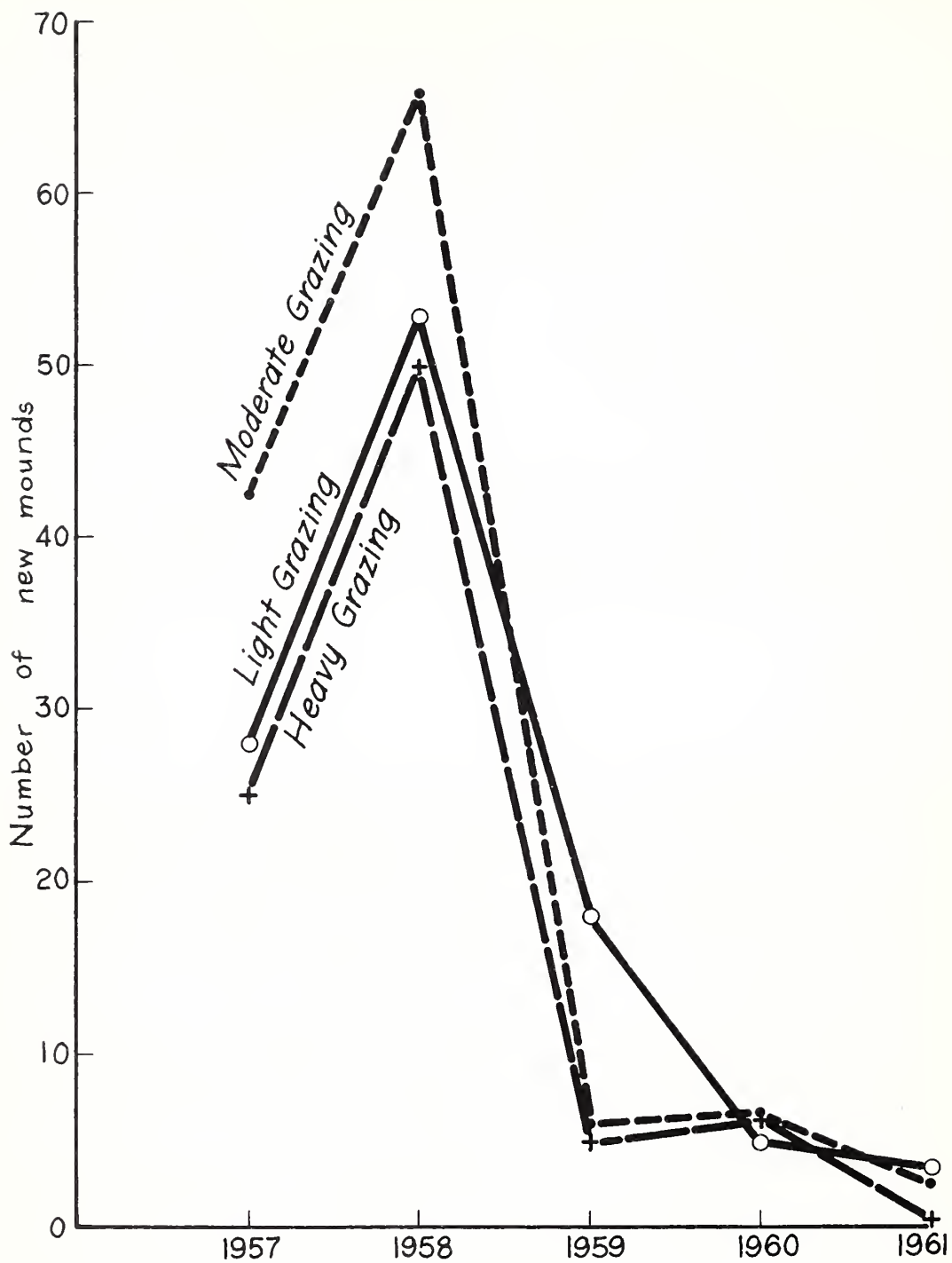


Figure B-1. --Annual trends in pocket gopher population depicted by number of new mounds made in 24-hour period on permanent plots in September 1957-61.



Figure B-2. --Soil disturbance by pocket gophers, particularly mound building, has been at a low point at Black Mesa. The appearance of new mounds on permanent plots after the old ones have been marked out has been used to study pocket gopher population trends on heavily, moderately, and lightly grazed range.

Table B-1. --Trends in vole population, expressed as catch per 100 trap nights, 1954-61

Year	Grazing treatment			Average
	Light	Moderate	Heavy	
----- <u>Number</u> -----				
Calibration period				
1954	1.4	0.3	0.6	0.8
1955	--	--	--	--
1956	0	0	0	0
Treatment period				
1957	0	.8	0	.3
1958	2.7	2.5	1.1	2.1
1959	.3	2.7	.6	1.2
1960	0	0	.3	.1
1961	0	0	0	0

Obvious lows occurred in 1956 and 1961 when no animals were taken in the sampled areas. Even in 1958, the peak year for voles in the inventory period, the population was not high. The inventory indicates less than an animal per acre on the sampled areas.

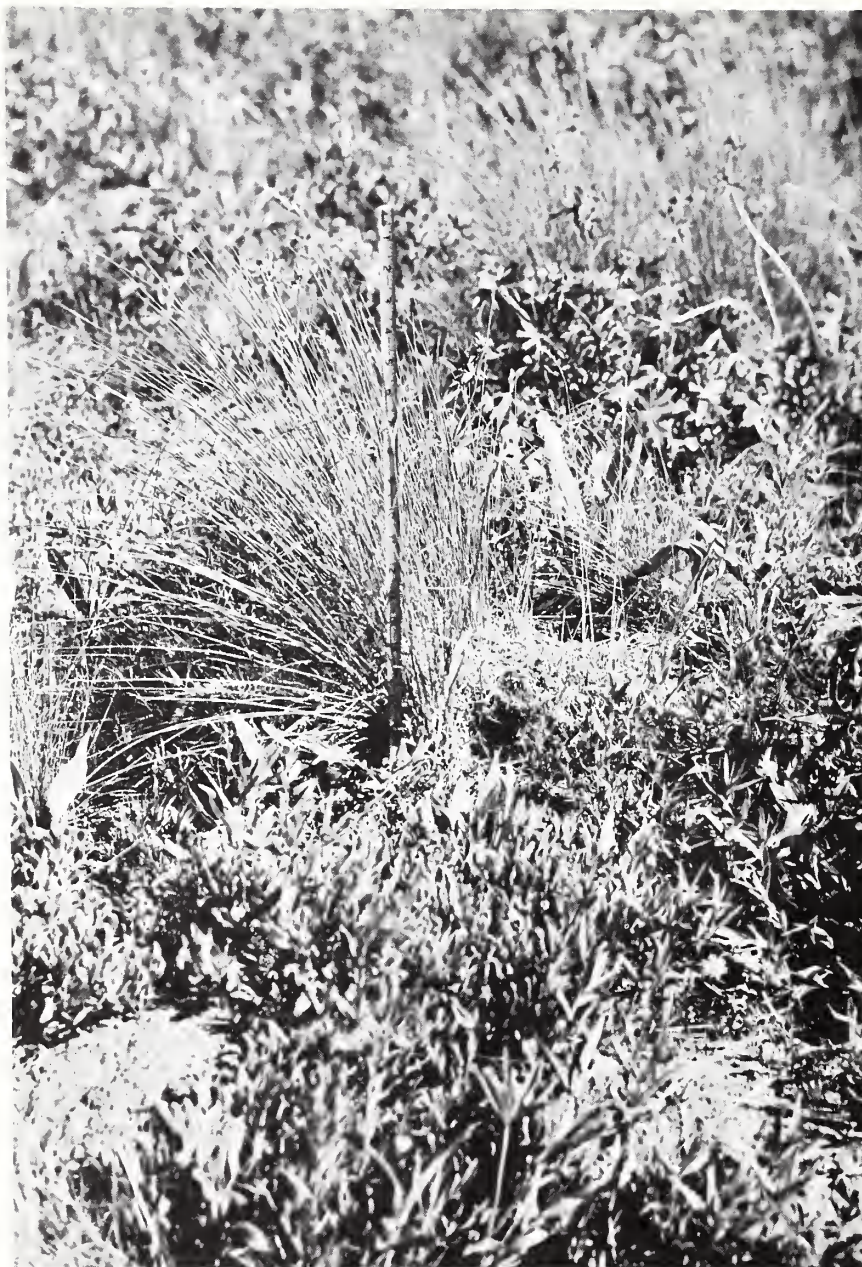


Figure B-3. --Hole and dead part of plant base to right of ruler show evidence of pocket gopher clipping on Thurber fescue bunchgrass during winter 1958-59. Following the pocket gopher decline on Black Mesa in 1959, this type forage loss has not been extensive.

Seed-eating small mammals not
abundant on Fool Creek watershed

Deer mice, chipmunks, and shrews were present, but not numerous, in the strip-cut lodgepole pine and spruce-fir forest types of the Fool Creek watershed, Fraser Experimental Forest, Colorado (fig. B-4). These species of seed-eating mammals are frequently considered important sources of seed loss and detrimental to natural forest regeneration on logged areas.

In one annual inventory 2 years before logging began (1952), and in five others in subsequent years, beginning 1 year after cutting was completed, population levels of these small mammals were not found to be high or critical on the Fool Creek watershed (table B-2).

Table B-2. --Catch of seed-eating animals per 100 trap
nights, 1952-61

Year	Deer Mice		Chipmunks		Shrews	
	Cut	Uncut	Cut	Uncut	Cut	Uncut
	area	area	area	area	area	area
	----- Number -----					
Pretreatment						
1952	--	0	--	1.0	--	0.7
Posttreatment						
1957	0.3	0	2.5	1.7	0	0
1958	.3	.3	.8	.3	0	0
1959	.6	0	4.2	.8	0	.6
1960	1.7	2.8	5.5	.8	4.2	2.2
1961	.3	0	4.2	.6	.6	0
Average	.6	.5	3.4	.9	1.0	.6

For each of the three species, populations were never greater than about three animals per acre, and this high was only for chipmunks in 1959, 1960, and 1961, and shrews in 1960. In other years populations for each species were one or less animals per acre on the sampled areas.

Seemingly, the chipmunks preferred the cutover strips to the unlogged stands. Seed-producing herbaceous vegetation was limited in distribution and abundance on the uncut areas.

Red-backed, montane, and heather voles were also present in the Fool Creek watershed. These animals are frequently associated with foliage clipping and barking of basal areas and branches of seedling and sapling conifers (table B-3, fig. B-5).



Figure B-4. --Animals above ruler were taken on the strip-cut Fool Creek watershed; those below, on the adjacent uncut East St. Louis watershed. Top row, left to right, chipmunks, and red-backed voles; second from top, shrews, heather vole, and deer mice; third from top, deer mice, taken in 1 night's trapping on the Fool Creek watershed. Below ruler, shrew and red-backed voles taken on adjacent unlogged East St. Louis watershed.

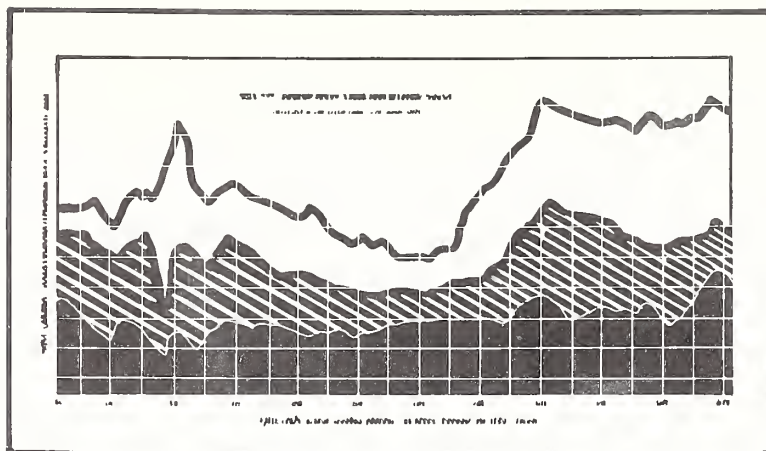
Table B-3. --Catch of three species of voles per 100 trap nights, 1952-61

Year	Redbacked voles		Montane voles		Heather voles	
	Cut area	Uncut area	Cut area	Uncut area	Cut area	Uncut area
- - - - - Number - - - - -						
Pretreatment						
1952	--	12.2	--	0	--	0
Posttreatment						
1957	11.4	8.6	18.6	5.3	0	.3
1958	2.8	3.0	1.9	1.7	0	0
1959	.3	.3	1.9	0	.6	.3
1960	.8	2.5	.3	0	.6	.3
1961	1.4	1.4	0	0	.8	.3
Average	3.3	4.7	4.5	1.2	.4	.2

Red-backed and montane vole populations were high, particularly on the logged strips, 1957. This was 1 year after the cutting on Fool Creek was completed. The cut strips were strewn with green slash that provided an abundance of food and cover for these animals. Evidence of extensive feeding on the inner bark and phloem of the slash was prevalent in 1957. Much of this feeding occurred in the winter of 1956-57 under the snow. However, as the logging debris dried out and deteriorated, this abundant food supply was lost, and vole populations declined. In the 4 years following the population peak, voles have not been numerous on the cut strips.



Figure B-5. --Foliage, stems, and branches of subalpine fir clipped and barked by voles. The feeding was done in winter under snow cover and extended 66 inches above ground level. Vole feeding on this advance fir reproduction occurred on one of the cut strips on the Fool Creek watershed.



Forest Economics Research

FOREST PRODUCTS MARKETING

Because of the growing interest in the prospects for making pulp and paper in the central Rocky Mountain area, a feasibility analysis was started 2-1/2 years ago. The 5 million board feet of timber lost to bark beetles in the late 1930's and the 1940's on the White River and other National Forests of western Colorado focused attention on the need for utilization. The feasibility analysis was primarily concerned with (1) the timber inventory, (2) establishing the general level of wood procurement costs, and (3) estimates of allowable mill capacities based on available water supplies. Other factors that influence the location of pulp and paper mills were also considered: transportation facilities, electric power, fuels, mill sites, labor, taxes, and living conditions. The results of the analysis indicate that the wood and water resources of the 13-million-acre study area can support substantial volumes of pulp- and paper-making indefinitely. A detailed report of the feasibility analysis will be published in 1962.

FOREST SURVEY

Forest Survey at resource
analysis stage in Colorado
and Wyoming

Inventory and area-Compilation phases of the Forest Survey are completed in Colorado and Wyoming. Data for preliminary results and detailed resource analysis are being machine compiled by the Pacific Southwest Forest and Range Experiment Station.

Area compilation of the South Dakota Black Hills is in progress.

Forest Survey initiated in
Arizona and New Mexico

Initial Forest Survey work including a survey of lumber production and timber cut, assembling of available inventory data, handbook revisions, and preparation for inventory field work has been started in Arizona and New Mexico. These are the last two States to receive the initial Forest Survey.

Preliminary results of the timber cut survey revealed a total cut of 53, 113, 000 cubic feet from growing stock in Arizona in 1960, and 49, 431, 000 cubic feet in New Mexico the same year (table E-1).

Table E-1. --Output of primary timber products from growing stock in
Arizona and New Mexico, 1960

Product	Arizona		New Mexico	
	<u>M cu. ft.</u>	<u>Percent</u>	<u>M cu. ft.</u>	<u>Percent</u>
Sawlogs	52,826	99.5	47,315	95.7
Poles (telephone, transmission)	0	0	348	.7
Round mine timbers	20	(¹)	251	.5
Converter poles	39	.1	1,474	3.0
Other (excelsior bolts, houselogs, and miscellaneous posts, poles and timbers)	228	.4	43	.1
Total	53,113	100.0	49,431	100.0

¹ Less than 0.1 percent

State forest type
maps completed

General forest type maps have been completed for each State in the Station territory. They are to be published at 1:5,000,000 scale in the revised U. S. Atlas of Agriculture. The maps show Douglas-fir, ponderosa pine, lodgepole pine, fir-spruce, hardwoods, pinyon-juniper, and chaparral as separate types.

Nebraska's million-acre timber
resource described and analyzed

As reported in Station Forest Survey Release No. 4, Nebraska has 1 million acres of commercial forest land and a live timber volume of 568.2 million cubic feet. The elm-ash-cottonwood type makes up 60 percent of the commercial forest area, followed by ponderosa pine, bur oak, and hardwood-red cedar types.

The estimated volume of saw logs in 1955 was 1,437 million board feet. Cottonwood, ponderosa pine, elm, ash, and bur oak constitute 91 percent of the saw log volume. Most of the volume is in eastern Nebraska.

Current growth of 14 million cubic feet is nearly three times the annual cut. However, the valuable hardwoods such as walnut are being overcut. Principal resource problems are poor stocking, decreasing quality due to over-cutting of the better trees and species, and heavy grazing.

Variety of woods used
in manufacturing

Preliminary results of a nationwide study of wood use in manufacturing in 1960 showed that many kinds of wood and wood products are used in the Station area as part of finished products or in manufacturing processes. Much of this wood is imported from other States and foreign countries.

Uses were classified as follows: (1) products made for sale; (2) pallets, skids, and bases; (3) containers; (4) jigs, models, patterns, and flasks; and (5) dunnage, blocking, and bracing. The only industries in which incidence of use in all categories was found were those engaged in manufacturing machinery (other than electrical) and transportation equipment. Other industries having considerable diversification of use included chemical and allied products; petroleum and coal products; stone, clay, and glass products; rubber and plastic products; and primary metal industries (table E-2). Industries in which reports of nonuse by individual firms were frequent included meat, dairy, and grain-mill products; bakery products; beverages; printing and publishing; petroleum products; stone, clay, and glass products; fabricated metal products; and machinery.

Species that appeared most diverse in use, occurring in all five categories, were ponderosa pine, Douglas-fir (lumber and plywood), and red and white oaks. Plywood of several species and hardboard were also used. The greatest variety of species used within industries occurred in mill work and furniture manufacturing. These industries used medium- and high-quality wood of about 20 species, including eastern and western softwoods and domestic and foreign hardwoods. Many of the same woods were also used in the form of plywood by these industries. Wide variety in use of both softwood and hardwood species was also found in the manufacture of some fabricated metal products and musical instruments.

New houses mostly wood frame,
with nonwood siding and wood
floor-support system

The U. S. Forest Service study of new single-family FHA approved houses in 1959 revealed that seven out of 10 had wood-frame construction (table E-3). Six out of 10 had a basement or crawl space, and a floor-support system made largely of wood. However, most houses in the Southwest region were built on a concrete slab.

Table E-2. --Type of wood products used by industry, 1960¹

Industry	Products made for sale	Pallets, skids, or bases	Containers	Jigs, models, patterns, and flasks	Dunnage, blocking, and bracing
Food and kindred products		X	X		
Apparel and related products		X			
Millwork and other wood products (not incl. wood sold as lumber)	X				
Furniture and fixtures	X				X
Paper and allied products		X			X
Printing and publishing				X	
Chemicals and allied products		X	X		X
Petroleum and coal products	X		X	X	
Rubber and plastic products	X		X	X	
Leather and leather products ²					
Stone, clay, and glass products		X	X		X
Primary metal industries		X	X	X	X
Fabricated metal products	X		X		
Machinery, except electrical	X	X	X	X	X
Electrical machinery		X	X		
Transportation equipment	X	X	X	X	X
Instruments and related products	X				
Miscellaneous manufacturing (musical instruments, toys, sporting goods)	X	X	X		

¹ Based on reports from about 650 firms.² No use reported.

Table E-3. --Type of exterior wall construction used in FHA-insured, single-family detached houses, by geographic region, 1959

Exterior wall construction ¹	All regions	North-west	South-west	Lake States	Central States	Gulf States	North Atlantic	South Atlantic
	----- Percent -----							
Wood frame (total)	70	80	77	99	84	21	91	99
Lumber siding	7	27	(²)	26	13	3	2	2
Plywood siding	2	7	2	1	3	1	1	(²)
Fiberboard siding	5	7	1	7	17	1	1	1
Shake or shingle siding	6	4	2	1	13	(²)	14	1
Nonwood siding	44	28	68	54	28	14	65	79
Mixed siding	6	7	4	10	10	2	8	16
Masonry	29	15	22	(²)	16	79	4	(²)
Mixed	1	5	1	1	(²)	(²)	5	1
All types	100	100	100	100	100	100	100	100

¹ At least 75 percent of the construction of the exterior wall of each house included in a construction type category is of the type indicated by that category. For example, to be included under "wood frame," at least 75 percent of the exterior wall of a house must be of wood frame construction; if 60 percent is wood frame and 40 percent masonry, the house is classified as "mixed" construction.

² Less than 1 percent.

FOREST RECREATION

Outdoor forest recreation research project started

The use of National-Forest lands for outdoor recreation has equaled or exceeded the rate of population growth. In many areas this use has become the major use of public forest lands. The first step in starting an outdoor recreation research project has been the development of an analysis to determine the magnitude and relative importance of the problems pertaining to forest recreation. Several major problems were recognized, some of which were:

1. Problems of various kinds and concentrations of recreational use on existing and new recreation areas,
2. Problems involving the criteria for the location, layout, design, and facilities for recreation areas,
3. Problems of the compatibility of timber utilization, range and wildlife management on recreational use,
4. Problems of personal and social values resulting from recreational use.

Exploratory evaluations
provide the initial attack

In both the Rocky Mountain and Southwestern Forest Service Regions, exploratory evaluations have been undertaken to ascertain the characteristics of hunter use as a measure of recreational use on National-Forest lands. The evaluations seek to explore the kinds of hunter use on developed and undeveloped camp sites: to obtain a measure of equipment used by hunters, of the use of camp and warming fires, of damage to vegetation and soils, and of hunter's response to suggestions regarding camp cleanup, sanitation, and fire hazards. A special evaluation with the Southwestern Region deals with the development of criteria to classify and select new recreation sites. The initial step has been an inventory of existing sites where recreational use records have been maintained. An evaluation of the study results will lead to the development of a prediction procedure to determine the expected use of new sites developed for different purposes.

Opportunities for future
studies unlimited

To meet the public demand for outdoor recreation and to improve the public's enjoyment of a forest outing, several management problems of site location and development, sanitation, and safety are apparent. For example, studies relating to these problems involve the determination of why people visit outdoor forest areas, what they expect from them, how much they enjoy these areas, and what kinds of people want what kinds of outdoor recreation activities. A study of methods that will measure the effects of recreation use on different soils and vegetation and on water supplies would be helpful in developing guidelines for the management of recreation areas. Another important study deals with the economic impact of recreational areas on the stability of small mountain communities. Such a study would be helpful in placing recreation in its proper perspective in relation to other uses of the forests.

MULTIPLE USE EVALUATION

Beaver Creek multiple-use evaluation project

Multiple-use land management is under test on the Beaver Creek Watershed in Arizona. Located on the Coconino National Forest, the 250,000-acre watershed encompasses the ponderosa pine, alligator and Utah juniper, and semidesert vegetation types. The land products and uses to be evaluated include water, wood, forage, wildlife, and recreation.

Water yield. --Preliminary figures of water yield based on 3 years' data for three watersheds located between 5,000 and 5,500 feet elevation with predominately mature Utah juniper trees, show average annual streamflow of 0.5 area-inch. For three watersheds between 5,500 and 6,500 feet elevation, with open grassland and scattered alligator juniper trees, the average flow was 3.0 area-inches. Six watersheds at 6,500 to 7,200 feet elevation, with mature ponderosa pine and scattered Gambel oak, had average streamflow of 4.6 area-inches.

There is now a total of 17 stream gages on the Beaver Creek watershed. One was recently completed on the Bar-M Creek (fig. W-15) and an additional gage will soon be completed on Woods Canyon. These gages are on large watersheds and are designed to measure flashy sediment-laden summer floods as well as snowmelt runoff.

Forage production. --On each of the experimental watersheds production estimates of perennial grasses are determined annually. Recent values are: 16 pounds per acre on watersheds located in the 5,000 to 5,500 feet elevation zone; 147 pounds per acre on watersheds in the 5,500 to 6,500 elevation zone; and 65 pounds per acre on the higher elevation watersheds. On a watershed whose cover was changed from mixed ponderosa pine and Gambel oak to perennial grasses, production was estimated at 426 pounds per acre. All values are based on air-dry weights.

Grass species most important in forage production by zones were: side-oats grama and blue grama at the lower elevations; blue grama, side-oats grama, bottlebrush squirreltail, mutton bluegrass, and black dropseed on the intermediate elevation watersheds; mutton bluegrass, bottlebrush squirreltail, bluegrass, blue grama, and prairie Junegrass on watersheds above 7,000 feet.

Wildlife. --Wildlife investigations are made in cooperation with the Arizona Game and Fish Commission and the U. S. Fish and Wildlife Service. Results to date show that deer are well distributed throughout the pine and juniper types during the spring and summer, but they tend to concentrate in the juniper during the fall and winter. Elk are scattered widely. However, only in 1959 were they observed in the areas dominated by Utah juniper. In 1960 and 1961 no elk pellet groups were found in the juniper areas.

Elk especially, but also deer, have tended to concentrate in the area on which trees were cleared and grass planted (experimental watershed No. 11). For example, in 1961 pellet groups indicated that elk use was 20 times more, perhaps 100 elk days per acre, on the cleared area than on the surrounding forest.

The contents of rumens of deer killed during fall and winter on Beaver Creek were examined. Utah and alligator junipers and shrub live oak were a surprisingly large proportion of total contents. Mountainmahogany and cliff rose were present in lesser amounts.

Timber growth. --On Beaver Creek there are 32 growth plots in pine stands, which are a part of the continuous inventory plots of the Coconino National Forest. The plots were established in 1950 and remeasured in 1961. Difference in the two measurements give a ponderosa pine growth of 35 cubic feet per acre per year. Nearly all the growth was in trees less than 20 inches d. b. h.

Recreation. --Recreation is an important use of wildlands, but it is not easy to evaluate in quantitative terms. It is planned at Beaver Creek to determine the potential recreation use. The first step toward accomplishing this has been a study of the existing camp and picnic sites in areas similar to Beaver Creek, for which records of number of visits and length of stay are available. Analyses of this use in relation to the accessibility, site development, water supply, scenic factors, etc., are being made. From the results of these analyses, it will be possible to select the sites on Beaver Creek desirable for recreation and predict the amount of potential recreation in relation to other uses of the land.

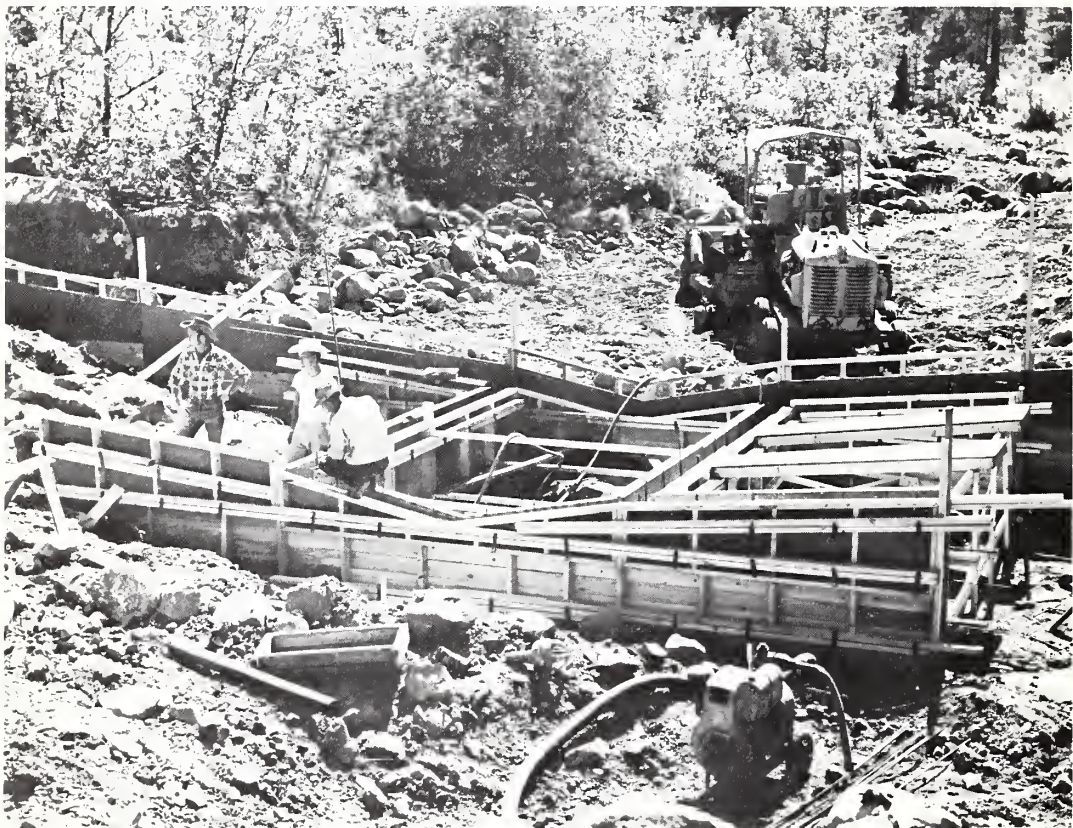
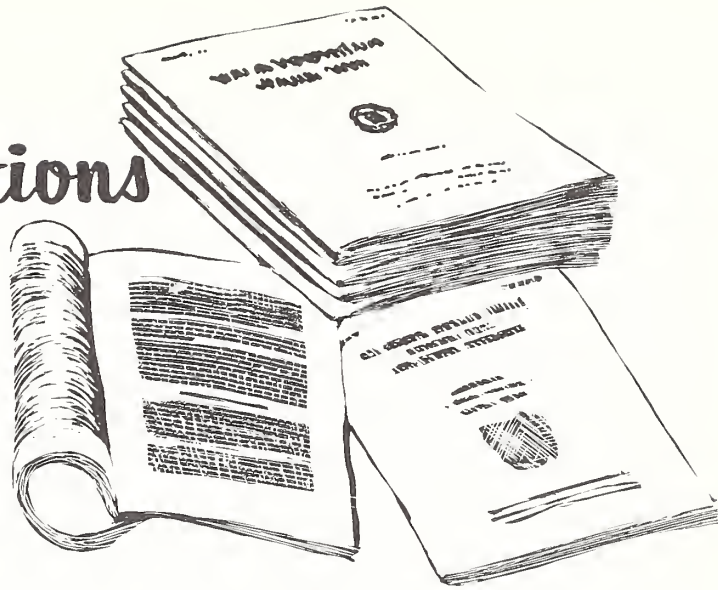


Figure W-15. --Construction of a stream gage on the Bar-M tributary of Beaver Creek in central Arizona. This watershed is 11,000 acres in size and is in the ponderosa pine zone.

Publications



FOREST MANAGEMENT AND FOREST FIRE RESEARCH

Heidmann, L. J., and Bierwagen, Walter.

An improved cone-drying rack. U. S. Forest Service Tree Planters' Notes 47, pp. 13-14, illus. [Processed.]

Describes a portable, rodentproof, cone-drying rack that will hold 12 to 15 bushels of cones.

Herman, Francis R.

Silvicultural control of dwarfmistletoe on southwestern ponderosa pine. Sta. Paper 62, 20 pp., illus. [Processed.]

Dwarfmistletoe can be controlled in lightly infected stands with minor modifications of current harvest cutting and stand improvement practices. In severely diseased stands heavier than normal cutting and substantial investments in direct control will be required.

Larson, M. M.

Seed size, germination dates, and survival relationships of ponderosa pine in the Southwest. Res. Note 66, 4 pp., illus. [Processed.]

Large-, medium-, and small-sized ponderosa pine seed were sown in field plots at weekly intervals from early June to August. Plots were watered regularly. Low nighttime temperatures appeared to delay germination in all June-sown plots until July. Seedlings that germinated in July survived much better than those that germinated in August. Seeds of different sizes germinated at about the same time and their seedlings survived equally well.

Lindenmuth, A. W., Jr.

Development of the 2-index system for rating forest fire danger.
Jour. Forestry 59: 504-509, illus.

This system, devised for the ponderosa pine forests of the Southwest, uses two independent indexes: a drought index based upon the moisture content of the top foot of bare soil and a rate-of-spread index based on the correlation of actual fire spread with air temperature, a litter-moisture factor, and wind. Moisture content in both indexes is estimated from cumulated differences in vapor pressure of the atmosphere and soil or fuel, adjusted for precipitation.

Using the 2-index system for rating forest fire danger.
Sta. Paper 63, 36 pp., illus. [Processed.]

A handbook for fire-weather observers and fire control officers covering all facets of forest fire danger rating, with emphasis on interpreting and applying the two indexes, or translating fire danger ratings into efficient fire control action.

Minor, Charles O.

Converting basal area to volume.
Res. Note 70, 2 pp. [Processed.]

"Plotless cruising" permits rapid measurement of the basal area of forest stands. Converting factors are presented which permit rapid conversion of basal area to volume in board feet (Scribner Decimal C), cubic feet, and rough cords. The only information needed is basal area and merchantable height or total height of trees.

Pulpwood volume tables for ponderosa pine in Arizona.
Res. Note 69, 6 pp. [Processed.]

Eight separate volume tables are presented which express merchantable volumes of pulpwood of southwestern ponderosa pine in terms of cubic feet and rough cords, based upon d.b.h. outside bark and either total heights or merchantable heights. Diameters are expressed in two ways: the conventional way (i.e., the 8-inch class includes diameters of 7.6 to 8.5 inches), and for convenient machine calculation (i.e., the 8-inch class includes diameters from 8.0 to 8.9 inches).

Myers, Clifford A., Jr.

Variation in measuring diameter at breast height of mature ponderosa pine. Res. Note 67, 3 pp. [Processed.]

Of 2,450 measurements of the diameters of 50 trees by 49 individuals, about 62 percent were correct. Ninety-four percent of the measurements were within 0.1 inch of modal diameter. The 49 differences between test and "true" volumes of all 50 trees ranged from 22 percent smaller than to 38 percent larger than 5-years' increase in volume.

Myers, Clifford A., and Van Deusen, James L.

Growth of immature stands of ponderosa pine in the Black Hills.
Sta. Paper 61, 14 pp. [Processed.]

Presents equations and tables for estimating future average diameter, basal area, and total cubic-foot volume from present measurements of these variables plus site index, stand age, and number of trees per acre. Factors for converting total cubic feet to merchantable cubic feet and cords are also given.

Peterson, Geraldine.

Board-foot volumes of Engelmann spruce to an 8-inch top.
Res. Note 56, 2 pp. [Processed.]

Presents board-foot volumes above stump to 8-inch top diameter, by 0.5 log heights. Primarily for use in Arizona and New Mexico.

Volume tables for aspen in Colorado.
Res. Note 63, 4 pp. [Processed.]

Three gross volume tables for aspen in Colorado are given: Board foot tables in 0.5 logs to 6-inch top and to 8-inch top, and a cubic-foot table to total height. Formulas for their computation are presented.

Read, Ralph A.

Bibliography of Great Plains Forestry.
Sta. Paper 58, 153 pp. [Processed.]

A listing of 1,768 references keyed to a subject-matter index covering publications from 1870 through 1959 on (1) all phases of tree planting, the uses and values of windbreaks, and the natural forests in the Great Plains of United States and Canada, and (2) windbreak influences studies throughout the world.

Ronco, Frank.

Planting in beetle-killed stands. Res. Note 60, 6 pp., illus. [Processed.]

Summarizes results of planting studies in beetle-killed spruce stands: Spruce seedlings survive better when shaded, and most mortality occurred during the winter months. Lodgepole pine was not affected by shading. Neither drought nor frost heaving were important causes of mortality with either species.

Selected bibliography of Engelmann spruce and subalpine fir.
Sta. Paper 57, 58 pp., illus. [Processed.]

This bibliography, limited to American and Canadian publications, covers literature pertaining to Engelmann spruce and subalpine fir. Since it was designed primarily as a working tool for forest managers, emphasis was placed on management aspects, and other subjects are not completely covered.

Simon, Charles L.

Effects of lifting date, cold storage, and grading on survival of some coniferous nursery stock. Jour. Forestry 59: 449-450.

The above-average grade of planting stock survived significantly better than the below-average grade for all three species. Cold storage had no significant influence on over-all survival. Seedlings that were lifted from the time snow melted (April 6) until 1 week (spruce) and 3 weeks (lodgepole pine) after first bud swelling survived equally well. Later liftings did not survive so well after cold storage. Ponderosa pine remained apparently dormant through the period of study and survived equally well for all treatments.

FOREST INSECT RESEARCH

Amman, Gene D., and Baldwin, Paul H.

A comparison of methods for censusing woodpeckers in spruce-fir forests of Colorado. Ecology 41: 699-706, illus.

Nine methods of censusing woodpecker populations were tested for use in forecasting their effectiveness in suppressing Engelmann spruce beetle outbreaks. The variable-width-strip method was best.

Baldwin, Paul H.

Overwintering of woodpeckers in bark beetle-infested spruce-fir forests of Colorado. Internatl. Ornith. Cong. Proc. 12: 71-84, illus.

Three species of woodpeckers--northern three-toed, hairy, and downy--aggregate in Engelmann spruce beetle outbreak centers during the winter and feed on the larvae. They disperse during the breeding season.

Knight, Fred B.

The effects of woodpeckers on populations of the Engelmann spruce beetle. In Technical Writing. G. P. Wellborn, L. B. Green, and K. A. Nall, pp. 332-339, illus. Houghton Mifflin Co., Boston. (Reprinted from Jour. Econ. Ent. 51 (5): 603-607, illus.)

This article was reprinted in the textbook as an example of a technical paper.

Variations in the life history of the Engelmann spruce beetle. Ent. Soc. Amer. Ann. 54: 209-214, illus.

Describes the 2- and 3-year life cycle of the insect and influence of these variations on population trends.

Massey, Calvin L.

Biology of the southwestern pine beetle, Dendroctonus barberi.
Ent. Soc. Amer. Ann. 54: 354-359, illus.

Reports the life history and habits of the beetle. Included is a list of insects found associated with the pest, many of which may be parasites and predators.

Pierce, Donald A.

Classes of ponderosa pine in New Mexico and Arizona susceptible to attack by the southwestern pine beetle and associated bark beetles. Sta. Paper 64, 9 pp., illus. [Processed.]

A study to determine whether tree susceptibility to bark beetle attack can be identified in ponderosa pine stands of the Southwest. Keen's Tree Classification and Salman and Bongberg's Risk Rating System were used to classify susceptibility. Either method can be adapted to marking ponderosa pine stands in the Southwest.

Shaw, Elmer.

The bark bug's enemy. In Technical Writing.
G. P. Wellborn, L. B. Green, and K. A. Nall. pp. 142-144, illus.
Houghton Mifflin Co., Boston. (Reprinted from Colo. Outdoors 7(4): 24-25.)

A popular article. Briefly describes research on the effects of woodpeckers on the Engelmann spruce beetle in Colorado.

Strange new weapons in an old war.

Empire Section, Denver Post 12 (33): 16-17, illus.

A popular photo story telling about recent research on the Engelmann spruce beetle.

Station Staff (Insect Division).

Forest insect conditions in central and southern Rocky Mountains, 1960. Sta. Paper 56, 15 pp., illus. [Processed.]

Issued as a supplement to the 1960 annual report. Summarizes results of recent insect surveys.

FOREST DISEASE RESEARCH

Eslyn, Wallace E.

New records of forest fungi in the Southwest. Mycologia 52: 381-387.

Lists and describes 18 different fungi believed to be new host or regional records for Arizona or New Mexico.

Gill, Lake S., and Hawksworth, Frank G.

The mistletoes. U. S. Dept. Agr. Tech. Bul. 1242, 87 pp.

Reviews the world literature on the mistletoe family (Loranthaceae). More than 800 references are cited.

Hawksworth, Frank G.

Abnormal fruits and seeds in Arceuthobium. Madroño 16: 96-101, illus.

Describes abnormal two-seeded fruits and seeds with double embryos in two dwarfmistletoes (Arceuthobium).

Dwarfmistletoe brooms and other brooms in lodgepole pine.

Res. Note 59, 3 pp., illus. [Processed.]

Describes nonparasitic lodgepole pine brooms frequently mistaken for those caused by dwarfmistletoe.

Dwarfmistletoe of ponderosa pine in the Southwest. U. S. Dept. Agr. Tech. Bul. 1246, 112 pp., illus.

Summarizes the available information on this dwarfmistletoe and includes results of investigations on its life history, seed flight, seed dispersal period, rate of spread through ponderosa pine stands, effects on host growth, and witches'-broom formation.

Dwarfmistletoes of ponderosa pine. Recent Adv. in Bot. 2: 1, 537-1, 541.

Discusses primarily the physiology and ecology of Arceuthobium vaginatum f. cryptopodum.

Observations on Arceuthobium vaginatum in Mexico. Madroño 16: 31-32.

Describes the hosts attacked by this dwarfmistletoe in Mexico. Includes one previously unrecorded host, Pinus pseudostrobus.

and Andrews, Stuart R.

Guides for pruning dwarfmistletoe-infected ponderosa pine branches. Res. Note 64, 3 pp. [Processed.]

Gives recommendations for pruning dwarfmistletoe-infected ponderosa pine branches based on studies of 445 pruned branches on the Fort Valley Experimental Forest, Arizona.

and Johnson, Norman E.

Guides for pruning dwarfmistletoe-infected lodgepole pine branches. Res. Note 65, 4 pp. [Processed.]

Gives recommendations for pruning dwarfmistletoe-infected lodgepole pine branches based on dissection studies of 170 branches from four National Forests in Colorado and Wyoming.

Peterson, Roger S.

Conifer tumors in the central Rocky Mountains. U. S. Agr. Res. Serv., Plant Dis. Rptr. 45: 472-474, illus. [Processed.]

Describes epidemic tumor development in Wyoming lodgepole pine and other species, with notes on possible causes.

Host alternation of spruce broom rust. Science 134 (3477): 468-469.

The life cycle of spruce broom rust was worked out by inoculations in the greenhouse. The fungus has kinnikinnick (Arctostaphylos) as alternate host.

On "facultative heteroecism." Phytopathology 51: 266-267.

Reviews several life cycles of rust fungi, previously known by one confusing name, and suggests alternative names.

Western gall rust cankers in lodgepole pine. Jour. Forestry 59: 194-196, illus.

Describes the development of trunk cankers (usually from branch galls) in lodgepole pine. Cull in mature trees, rather than seedling mortality, is the chief form of damage by western gall rust.

Shaw, Elmer W.

The dwarfmistletoe. Empire Magazine, Denver Post 12 (50): 8, illus.

A popular article that points out some of the fascinating characteristics of dwarfmistletoe and how it differs from the mistletoe used in Christmas decorations.

Weihsing, John L., Inman, Robert, and Peterson, Glenn W.

Response of ponderosa and Austrian pine to soil fumigants and seed treatments. U. S. Agr. Res. Serv., Plant Dis. Rptr. 45: 799-802, illus. [Processed.]

Significantly taller and heavier ponderosa pine seedlings were obtained by soil fumigation with Vapam and Dowfume MC-2. Denser stands were obtained by pelleting ponderosa pine seeds with Arasan and Captan.

FOREST UTILIZATION RESEARCH

Conway, E. M., and Minor, C. O.

Specific gravity of Arizona ponderosa pine pulpwood. Res. Note 54, 3 pp., illus. [Processed.]

Shows specific gravity at various heights within the tree based on increment core method of measurement.

_____, Minor, C. O., and Jones, D. D.
Sawing time for Arizona ponderosa pine logs.
Res. Note 55, 2 pp., illus. [Processed.]

Graphically presents estimated time required to saw logs of various scaling diameters.

Landt, Eugene F.
Forest industries of the Black Hills area--South Dakota and Wyoming.
Sta. Paper 60, 14 pp., illus. [Processed.]

Describes present characteristics, operations, and products of the forest industries and relates their activities to the available timber resources.

Mueller, Lincoln A.
Veneer and plywood possibilities from low-grade logs. In New horizons for Black Hills and Wind River lumber. Chicago and Northwest. Ry. Sawmill Clinic Proc. 1961: 34-39, illus. [Processed.]

Compares present plywood and lumber markets, and describes basic plant requirements and costs.

WATERSHED MANAGEMENT RESEARCH

Aldon, Earl F.
Instructions for maintenance and adjustment of FW-1 water level recorders. Sta. Paper 67, 14 pp., illus. [Processed.]

Describes the tools needed and outlines detailed steps necessary to keep FW-1 water level recorders in proper working order.

Berndt, Herbert W.
Some influences of timber cutting on snow accumulation in the Colorado Front Range. Res. Note 58, 3 pp., illus. [Processed.]

Significant increase in snowpack moisture content was found only when ponderosa pine-Douglas-fir stands were commercially clear cut. Increased melt rates resulted from two intensities of cutting.

Decker, John P.
Salt secretion by Tamarix pentandra Pall. Forest Sci. 7: 214-217, illus.

Reports a study of the morphology, anatomy, and physiology of salt glands of this halophytic phreatophyte.

Dortignac, E. J.
The Rio Puerco -- past, present, and future. N. Mex. Water Conf. Proc. 5: 45-51, illus. [Processed.]

History of grazing, cutting of main and tributary stream channels, and decline of irrigation are discussed. Rehabilitation and research programs with preliminary results of studies are given.

_____ and Love, L. D.

Infiltration studies on ponderosa pine ranges of Colorado.
Sta. Paper 59, 34 pp., illus. [Processed.]

Describes results of infiltrometer studies conducted in the ponderosa pine-bunchgrass country of the Rocky Mountains. Infiltration varied according to cover type, weight of organic materials, quantity of noncapillary pores in the surface soil, and protection from cattle grazing. A formula developed at Manitou was found suitable for estimating infiltration rates on another area.

Gary, Howard L.

A simple device for measuring fluctuations in shallow ground-water wells.
Res. Note 68, 2 pp., illus. [Processed.]

Describes a float and tape device used for measuring periodic fluctuations in water-table height.

_____ and Rich, Lowell R.

Nitrogen aids plant growth on Arizona soils derived from granite and diabase. Res. Note 57, 2 pp. [Processed.]

Summarizes a greenhouse "pot test" using barley plants to study fertility levels of granitic- and diabase-derived soils.

Glendening, G. E., Pase, C. P., and Ingebo, P.

Preliminary hydrologic effects of wildfire in chaparral. In *Modern techniques in water management*. Ariz. Watershed Symposium 5:12-15, illus. [Processed.]

Shows effects of a severe wildfire in chaparral in the 3-Bar watersheds near the Roosevelt Dam in Arizona.

Horton, J. S.

Ecology of salt cedar. In *Watershed and related water management problems*. Ariz. Watershed Symposium Proc. 4:19-21, illus. [Processed.]

Presents recent findings on the ecology of five-stamen tamarisk and outlines their application to control of this undesirable species.

Love, L. D.

Management of alpine and subalpine mountainous areas for water yield.
N. Mex. Ann. Water Conf. Proc. 5:39-44, illus. [Processed.]

Summarizes annual water yield from major vegetation types in southern Rocky Mountains. Describes results of watershed experiments in these types and outlines how a mountain watershed might be managed for effective water yields. The need for additional research is discussed.

Reynolds, Hudson G.

Vegetation management for water yield in the Southwest.
N. Mex. Ann. Water Conf. Proc. 5:21-33, illus. [Processed.]

Analyzes some of the principles of vegetation management in relation to water yields, and some of the possibilities for favoring water yields on watersheds in Arizona and New Mexico.

Rich, Lowell R.

Preliminary results of effect of forest tree removal on water yields and sedimentation--Workman Creek experimental watersheds. In Watershed and related water management problems. Ariz. Watershed Symposium Proc. 4: 13-16, illus. [Processed.]

Presents the changes in streamflow and sediment yields resulting from replacement of Douglas-fir-white fir type with perennial grass on 80 acres of a 248-acre forested watershed.

Surface runoff and erosion in the lower chaparral zone - Arizona. Sta. Paper 66, 35 pp., illus. [Processed.]

Summarizes surface runoff and erosion in the lower chaparral zone between 1925 and 1959 in nine small experimental watersheds. Surface runoff and erosion were reduced when a perennial grass cover was established.

, Reynolds, H. G., and West, J. A.
The Workman Creek experimental watershed. Sta. Paper 65, 18 pp. illus.

Describes watersheds, experimental design, treatments completed, results to date, and future research. Two timber-harvest treatments have been completed. Test of individual tree selection harvest resulted in no significant change in water yield, but clear cutting of one-third of a watershed and planting to grass resulted in a significant increase in water yields the second water year after treatment.

Skau, C. M.

Some hydrologic influences of cabling juniper. Res. Note 62, 2 pp. [Processed.]

Cabling juniper produces surface depressions, which annually trap an estimated 0.09 to 0.27 inch surface flow. Slash in immediate contact with the ground impedes surface flow.

Thompson, J. R.

Infiltrometer plot records. In A progress report--hydrologic and biotic characteristics of grazed and ungrazed watersheds of the Badger Wash basin in the arid lands of western Colorado, 1953-58. Coop. Proj. U. S. Geol. Survey, U. S. Forest Serv., U. S. Fish and Wildlife Serv., U. S. Bur. Reclam., and U. S. Bur. Land Mangt. pp. 43-62, illus. [Processed.]

Gives a comparison of infiltrometer plot records in 1953 before livestock were excluded, with these same data taken in 1958 after 5 years of excluding livestock from one of each of a series of four pairs of watersheds.

RANGE MANAGEMENT AND WILDLIFE HABITAT RESEARCH

Beetle, A. A., Johnson, W. M., Lang, R. L., May, Morton, and Smith, D. R.
Effect of grazing intensity on cattle weights and vegetation of the Bighorn experimental pastures. Wyo. Agr. Expt. Sta. Bul. 373, 23 pp., illus.

Describes response of animals and range vegetation of the Idaho fescue association on two soils to three intensities of grazing from 1951 to 1958. A proper use factor for seasonlong grazing was suggested.

Cable, Dwight R.

Small velvet mesquite seedlings survive burning.
Jour. Range Mangt. 14: 160-161, illus.

One-third of velvet mesquite seedlings burned when 8 and 12 months old were top killed only and sprouted later from the base; the other two-thirds were completely killed. Age of seedlings had no effect on the results.

_____ and Tschirley, Fred H.

Responses of native and introduced grasses following aerial spraying of velvet mesquite in southern Arizona. Jour. Range Mangt. 14: 155-159, illus.

Aerial spraying of velvet mesquite in two successive years with 2, 4, 5-T killed 36 to 58 percent of the trees and reduced mesquite foliage 86 to 95 percent. Increased herbage production of perennial grasses more than paid the treatment cost within 3 years.

Hickey, Wayne C., Jr.

Growth form of crested wheatgrass as affected by climate and grazing use. Ecology 42: 173-176, illus.

Crested wheatgrass in northern New Mexico changes from an upright to a spreading growth form with increasing intensity of grazing. On dry sites plants are more spreading than on moist sites when both are grazed at similar intensities. Past intensity of cattle grazing has a greater effect on growth form than does site.

_____ Relation of selected measurements to weight of crested wheatgrass plants.
Jour. Range Mangt. 14: 143-146, illus.

Shows correlation of plant weight with basal diameter, crown diameter, leaf height, culm height, compressed crown diameter, compressed leaf length, and compressed culm length. Also discusses effects of site and grazing.

Hurd, Richard M.

Grassland vegetation in the Big Horn Mountains, Wyoming. Ecology 42: 459-467, illus.

Describes and analyzes the plant cover of nine grassland areas, some of which had been ungrazed by livestock for many years.

Jameson, Donald A.

Growth inhibitors in native plants. Res. Note 61, 2 pp. [Processed.]

Reports the effect of ethyl alcohol and water extracts of plant material from 20 species on the growth of wheat radicles. Concludes that mere presence of growth-inhibiting substance may not be of ecological significance.

Heat and desiccation resistance of tissue of important trees and grasses of the pinyon-juniper type. Bot. Gaz. 122: 174-179, illus.

Resistance of plant tissue to heat treatments was highest in winter and lowest in early summer. Equations show that heat resistance was inversely related to depression of the wet bulb thermometer on the day of sampling. Tree tissues were always more resistant than grass tissues.

Keith, James O.

An efficient and economical pocket gopher exclosure.
Jour. Range Mangt. 14: 332-334, illus.

Describes a practical method of fencing and poisoning to prevent pocket gopher invasion of study areas.

Paulsen, Harold A. Jr., and Ares, Fred N.

Trends in carrying capacity and vegetation on an arid southwestern range.
Jour. Range Mangt. 14: 78-83, illus.

Long-term records from the Jornada Experimental Range show that because of wide fluctuations in precipitation a sustained grazing capacity does not exist on black grama-tobosa grass and associated shrub ranges of southern New Mexico. With shrub invasion of grasslands there is an increasing decline in grazing capacity.

Pond, Floyd W.

Basal cover and production of weeping lovegrass under varying amounts of shrub live oak crown cover. Jour. Range Mangt. 14: 335-337, illus.

Basal cover and production of seeded weeping lovegrass tended to be inversely proportional to amount of shrub live oak crown cover.

Effect of three intensities of clipping on density and production of meadow vegetation. Jour. Range Mangt. 14: 34-38, illus.

Reports effects of clipping at three intensities on density and production of native grasses and sedges, Kentucky bluegrass, and white Dutch clover. Plants were clipped to 1- and 3-inch stubble heights at 2-week intervals during the growing season, and to a 1-inch stubble in September only.

Mechanical control of Arizona chaparral and some results from brush clearing. In Modern techniques in water management. Ariz. Watershed Symposium Proc. 5: 39-41, illus.

Briefly discusses root plowing, burning, and use of herbicides in controlling brush and chaparral.

Reynolds, H. G.

Measuring range production. West. Agr. Econ. Res. Council Proc. Rpt. 9: 101-103.

Outlines range production factors that can be measured in terms of forage and animal products.

Springfield, H. W.

Shrub use by sheep on seeded range. Natl. Wool Grower 51(6): 14-15, illus. (Reproduction of Res. Note 49, 4 pp., illus.)

Describes heavy utilization of sagebrush and rabbitbrush by sheep during spring lambing on crested wheatgrass and gives explanations why shrubs were heavily grazed.

The grazed-plant method for judging the utilization of crested wheatgrass. Jour. Forestry 59: 666-670, illus.

Results are based on studies at four sites in northern New Mexico, 1948-59. Evaluates the grazed-plant method for determining utilization of crested wheatgrass and points out some limitations of the method.

Tschirley, Fred H., and Martin, S. Clark.

Burroweed on southern Arizona rangelands. Ariz. Univ. Tech. Bul. 146, 34 pp., illus.

A brief summary of what is known about burroweed (Haplopappus tenuisectus (Greene) Blake) from observations and research conducted in southern Arizona over a period of almost 60 years. The discussion includes taxonomy, life history, geographic distribution, relationship to cattle grazing, chemical composition, and methods of control. The results of 98 different herbicide treatments are listed in the appendix.

Turner, George T.

In A progress report--Hydrologic and biotic characteristics of grazed and ungrazed watersheds of the Badger Wash basin in the arid lands of western Colorado, 1953-58. Coop. Proj. U. W. Geol. Survey, U. S. Forest Serv., U. S. Fish and Wildlife Serv., U. S. Bur. Reclam. and U. S. Bur. Land Mangt. pp. 21-42, illus. [Processed.]

Describes and analyzes changes in plant and ground cover on salt desert-shrub winter range over a 5-year period on grazed and ungrazed watersheds.

FOREST BIOLOGY RESEARCH

Reid, Vincent H.

Trends in small rodent and rabbit populations. In A progress report-- hydrologic and biotic characteristics of grazed and ungrazed watersheds of the Badger Wash basin in the arid lands of western Colorado, 1953-58. Coop. Proj. U. S. Geol. Survey, U. S. Forest Serv., U. S. Fish and Wildlife Serv., U. S. Bur. Reclam., and U. S. Bur. Land Mangt. pp. 102-108. [Processed.]

Reports catch of small mammals on permanent snap-trap lines and rabbit population trends for grazed and ungrazed watersheds in the Badger Wash basin.

FOREST ECONOMICS RESEARCH

Stone, Robert N., and Bagley, Walter T.

The Forest Resource of Nebraska. Forest Survey Release 4, 45 pp., illus. [Processed.]

Presents a current estimate of the volume, area, location, and condition of major timber species, along with a description of major factors affecting tree growth and condition.

Worley, David P.

Objectives and methods of economic evaluation on the Beaver Creek watershed project. West. Agr. Econ. Res. Council Conf. Proc. Rpt. 9: 123-129. [Processed.]

Discusses important watershed studies underway on the Coconino National Forest in Arizona, with emphasis on multiple use.

